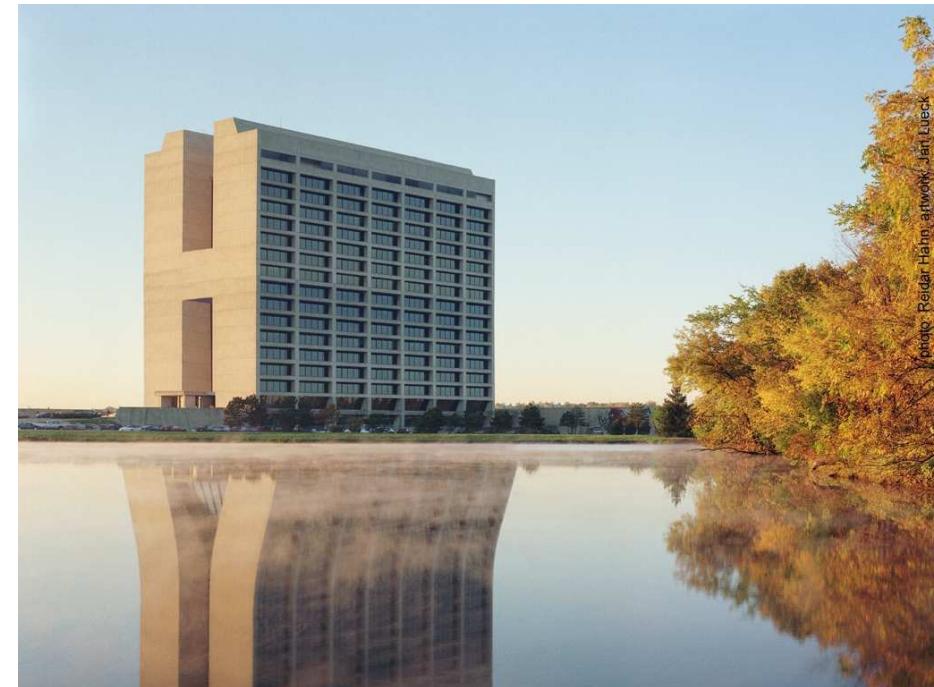
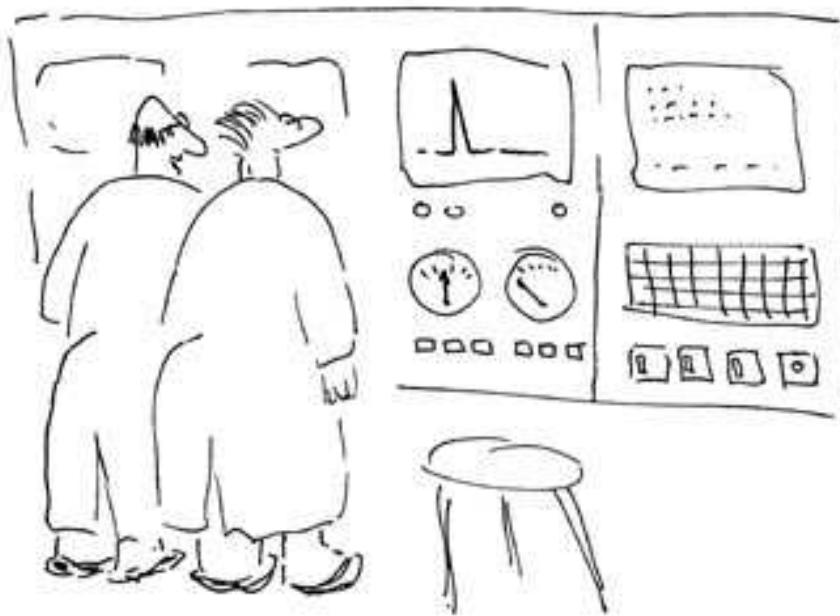




SM Higgs Boson Search Using a Matrix Element Technique at CDF

Bárbara Álvarez González, U. de Oviedo



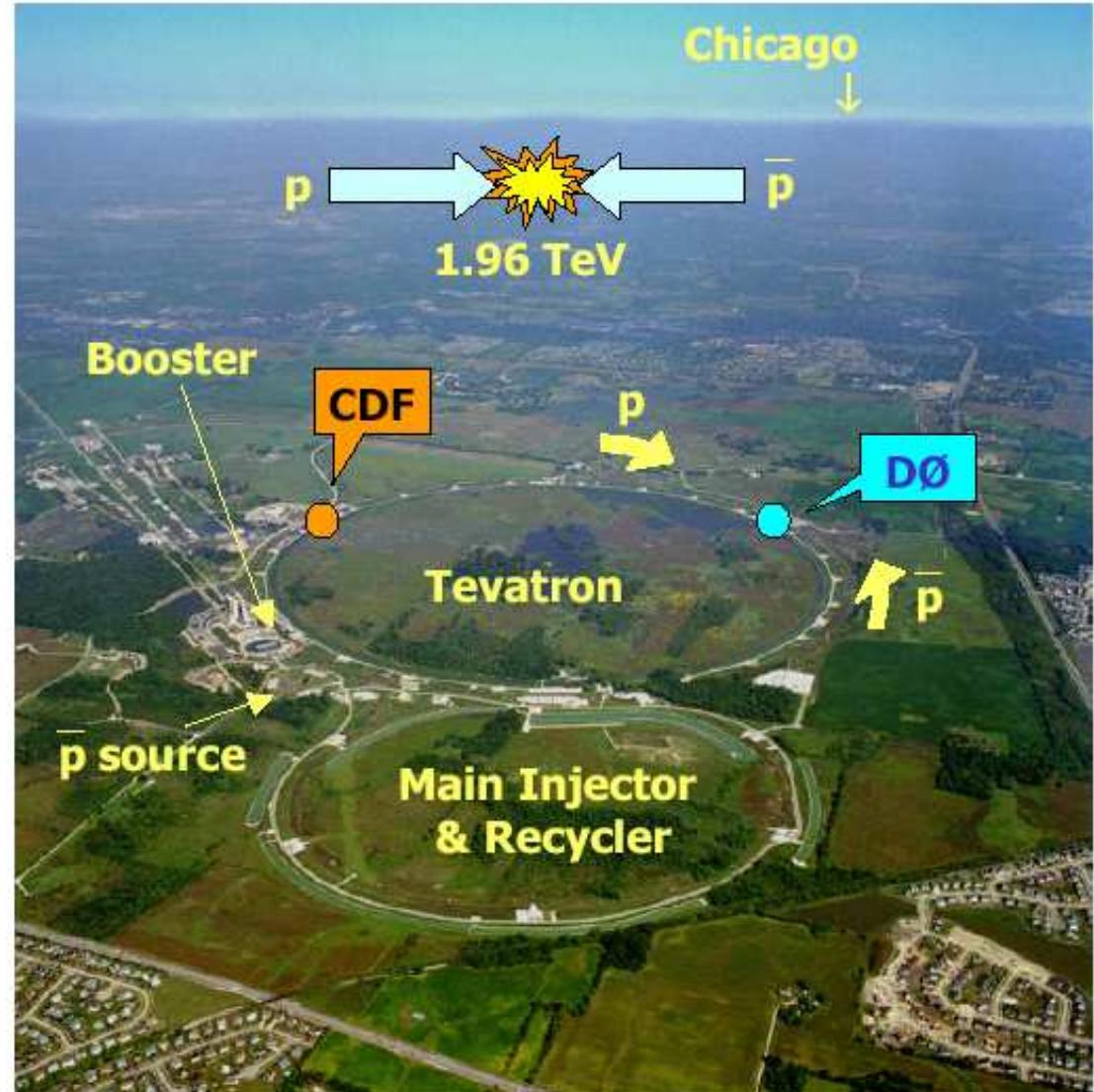
Fermilab Seminar, March 2nd, 2010

OUTLINE

- Tevatron and CDF.
- SM Higgs Boson.
- WH Event Selection.
- Background Estimate.
- Matrix Element Method.
 - ◊ Transfer Functions.
 - ◊ Event Probability Discriminant.
- Results.
- Summary and Outlook.

TEVATRON

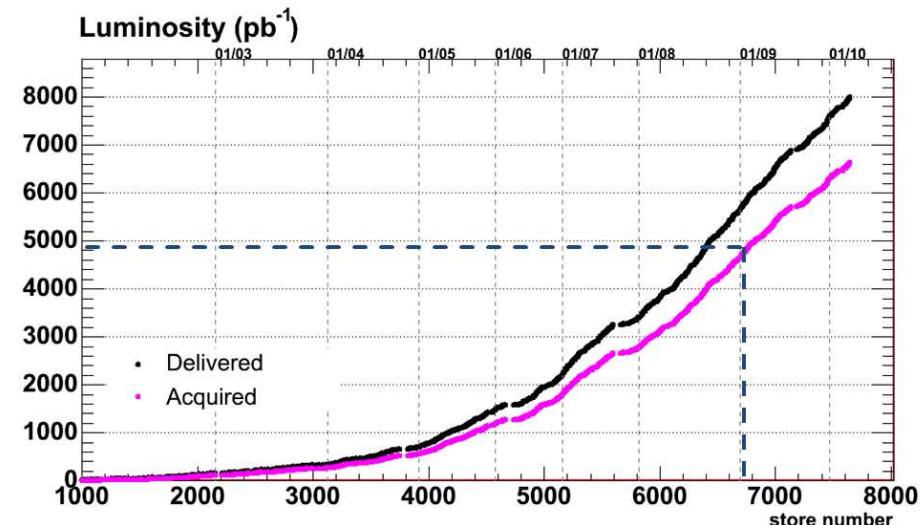
- Fermilab is home to the Tevatron.
- Fermilab's accelerator chain:
 - ◊ Cockcroft-Walton pre-accelerator (750 KeV).
 - ◊ Linac (linear accelerator) (400 MeV).
 - ◊ Booster Ring (8 GeV).
 - ◊ Main Injector (150 GeV).
 - ◊ Tevatron (980 GeV).
- The Tevatron is a $p\bar{p}$ collider:
 - ◊ 980 GeV per beam.
 - ◊ Collisions every 396 ns.
- Two collision points at the Tevatron: DØ and CDF.



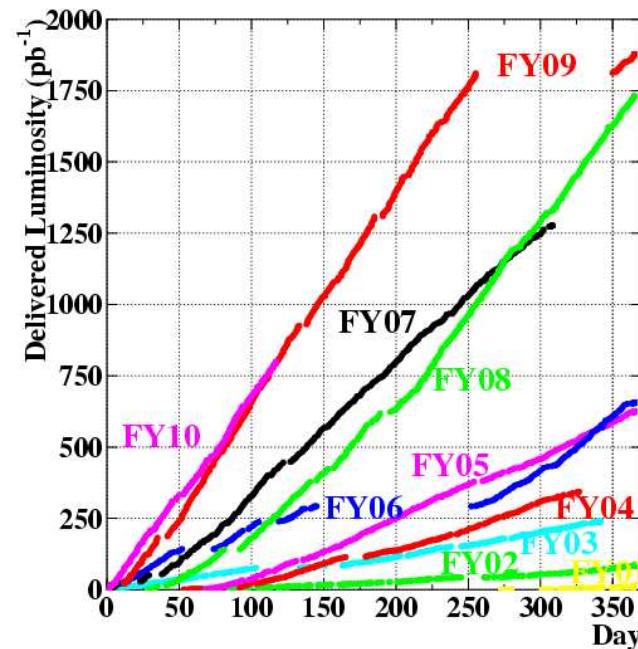
TEVATRON PERFORMANCE

- Tevatron delivered $> 7.8 \text{ fb}^{-1}$
 - ◊ Collected per experiment $> 6 \text{ fb}^{-1}$
 - ◊ 85 to 90 % of efficiency.

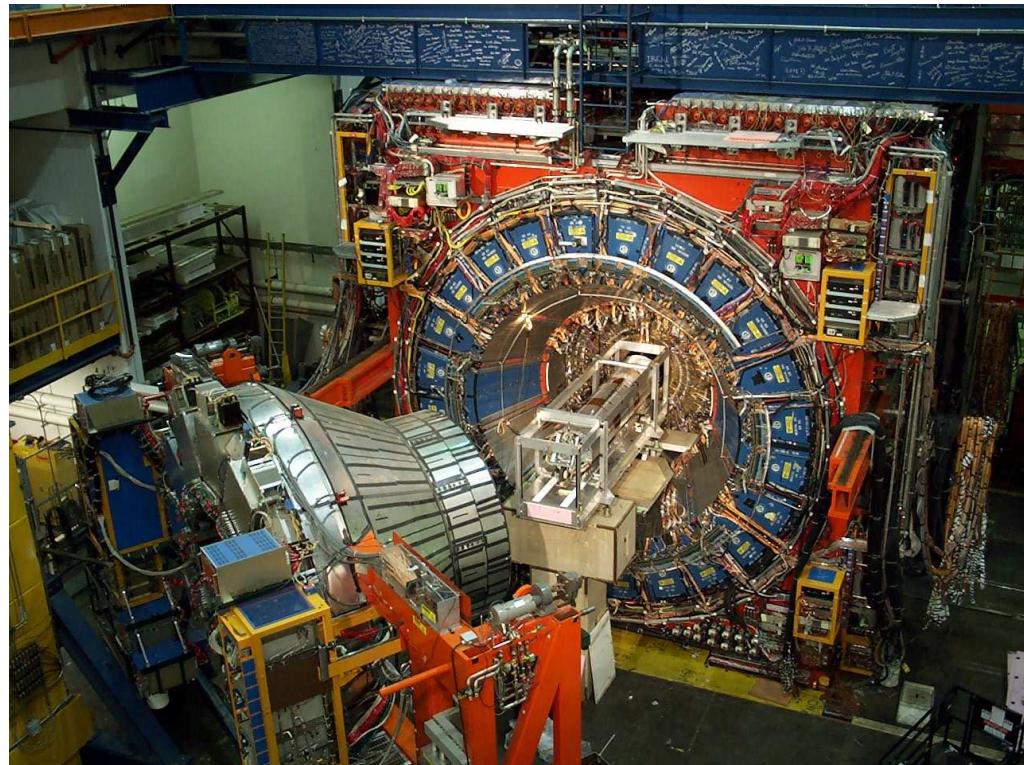
- This analysis uses 4.8 fb^{-1}



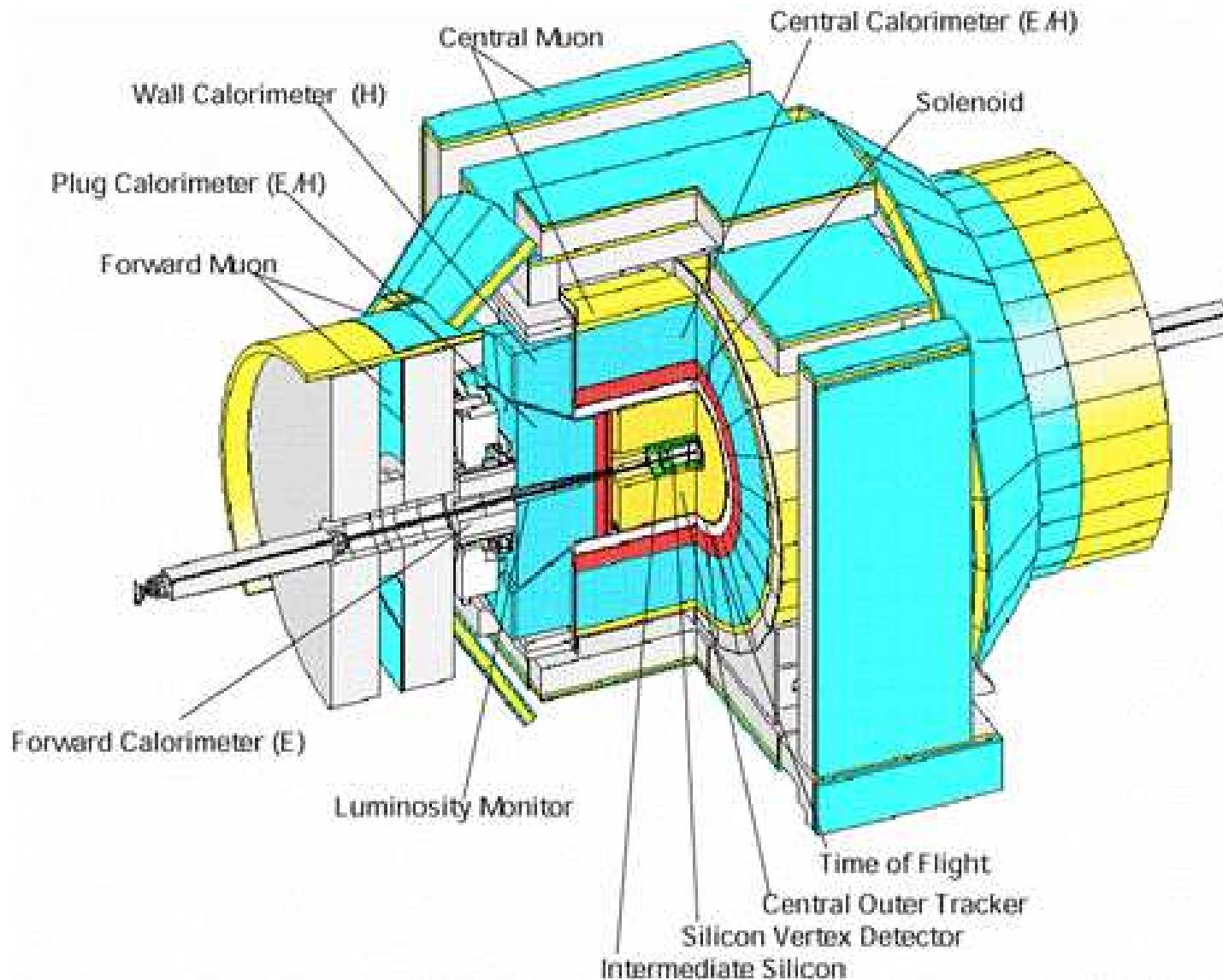
- Tevatron is performing very well:
 - ◊ Peak luminosity $\sim 360 \cdot 10^{30} \text{ cm}^{-2} \text{s}^{-1}$
 - ◊ Weekly integrated lum. $\sim 50 \text{ pb}^{-1}$
 - ◊ Run through 2010-11 ($9-11 \text{ fb}^{-1}$)



Detectors



CDF Detector



- The whole detector is needed for this analysis.

CDF Detector

- Silicon

$$\eta = -\ln(\tan \frac{\theta}{2})$$

- ◊ L00: $|\eta| \leq 4.0$
- ◊ SVX and ISL: $|\eta| \leq 2.0$
- ◊ Spacial Resolution: $\approx 20 \mu\text{m}$.

- Central Outer Tracker (**COT**):

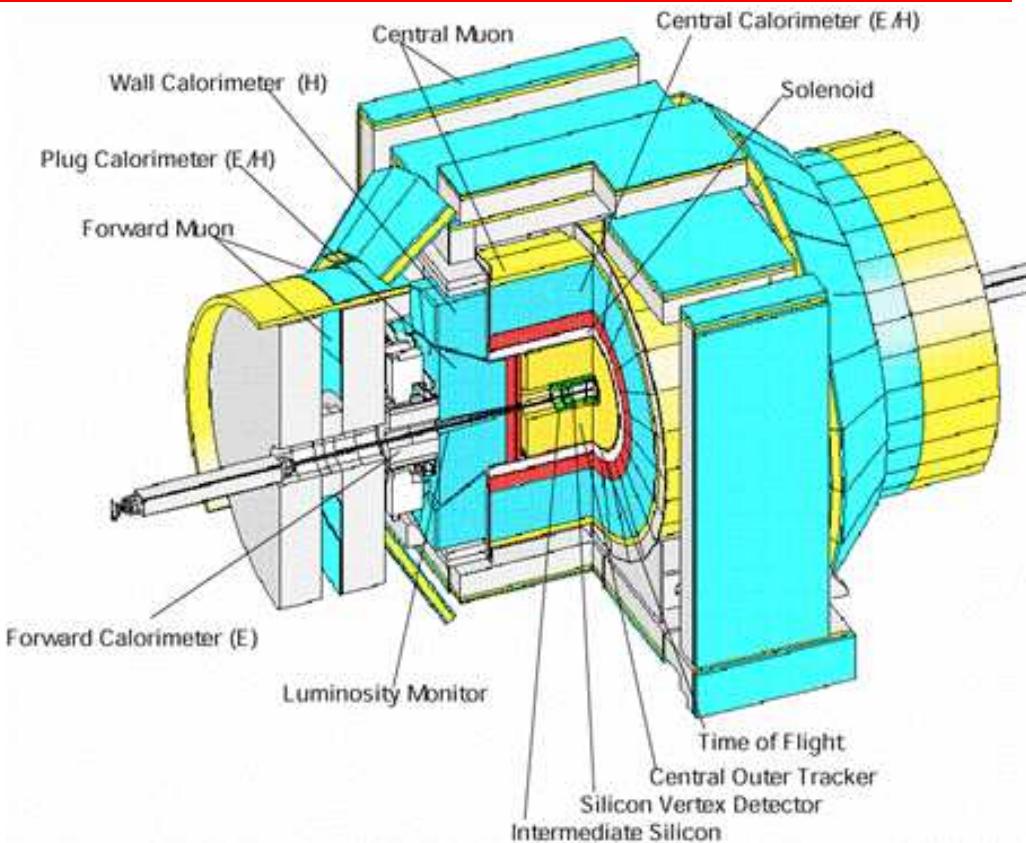
- ◊ $|\eta| \leq 1.0$
- ◊ Spacial Resolution: $\approx 140 \mu\text{m}$.
- ◊ Momentum Res.: $0.17\%[GeV/c]^{-1}$

- Calorimeter:

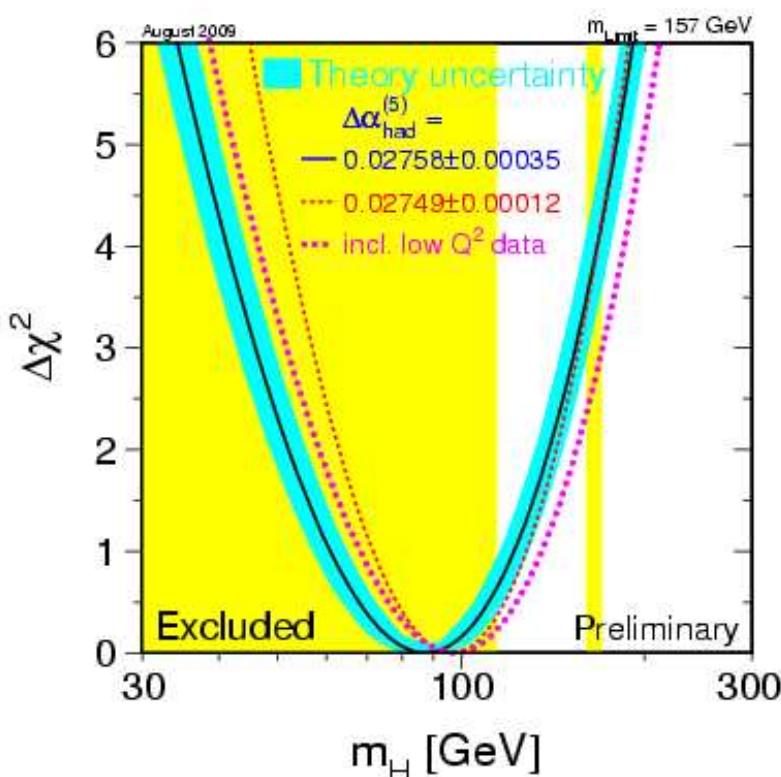
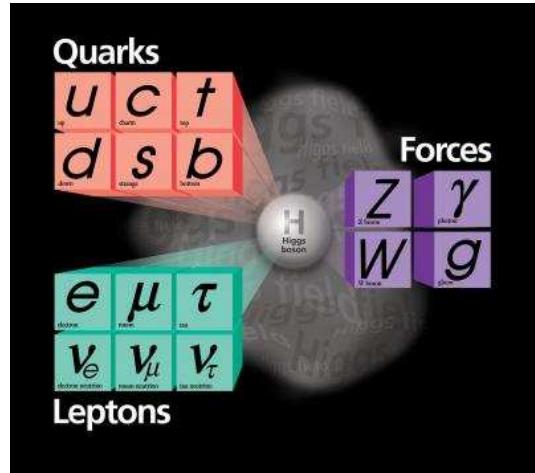
- ◊ $|\eta| \leq 3.6$
- ◊ Energy Resolution: $\frac{13.5\%}{\sqrt{E_T}} \oplus 2\%$

- Muon chambers:

- ◊ $|\eta| \leq 1.5$



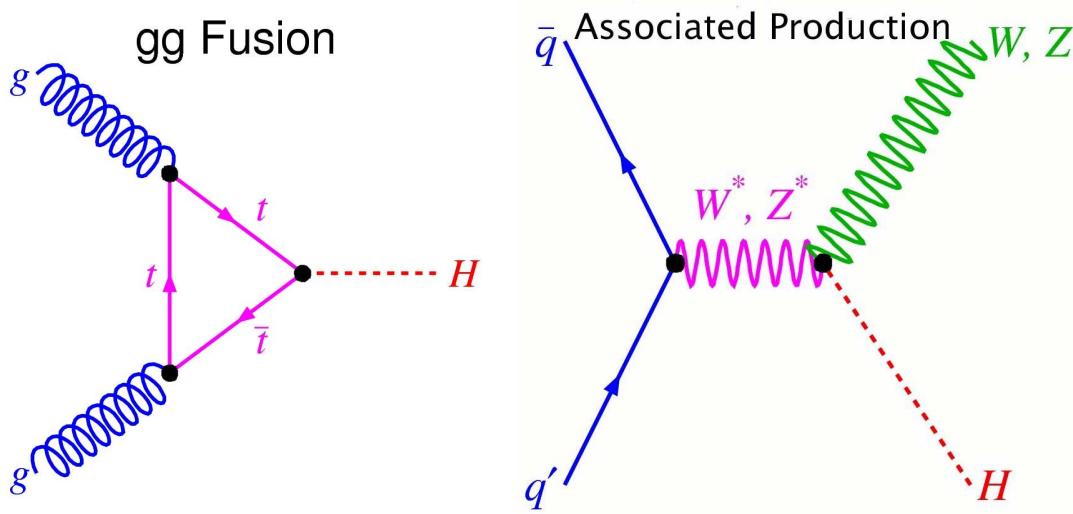
MOTIVATION: The Elusive Higgs boson



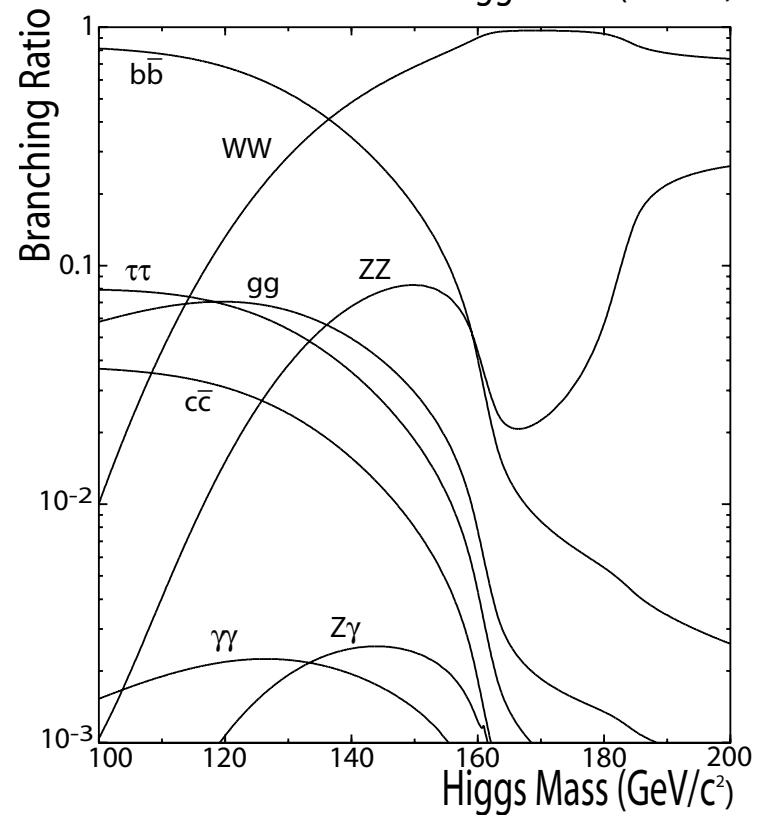
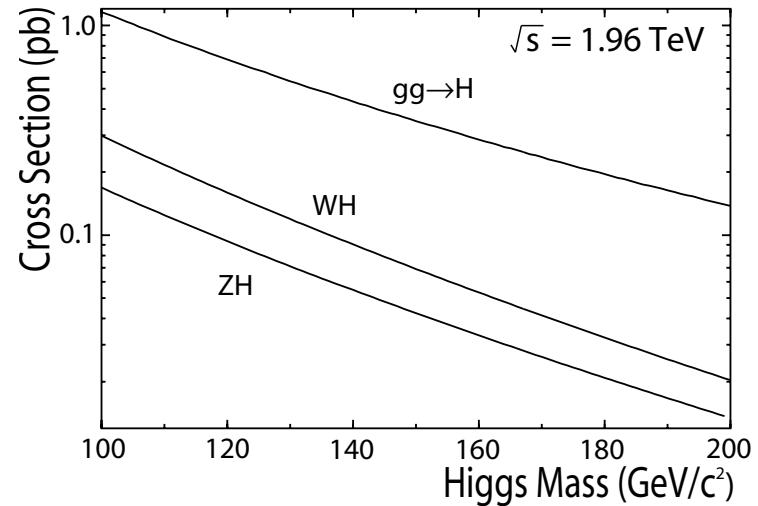
- Within SM, the Higgs mechanism is responsible for EWSB.
- It is the only Standard Model particle that has not been observed yet:
 - ◊ Direct searches at LEP: $m_H > 114.4$ GeV (95% C.L.)
 - ◊ Indirect EWK constrains: $m_H < 157$ GeV (186 GeV)
- The preferred value for its mass is:
 - ◊ $m_H = 87^{+35}_{-26}$ GeV.
- CDF and DØ are pursuing a direct search for a SM Higgs over a wide mass range:
$$100 < m_H < 200 \text{ GeV}$$

SM Higgs at the Tevatron

- Gluon-gluon fusion is the dominant production channel ($gg \rightarrow H$) $\sigma \sim 1 \text{ pb}$
- Next is the associated production with a vector boson (WH, ZH) $\sigma \sim 0.1 \text{ pb}$

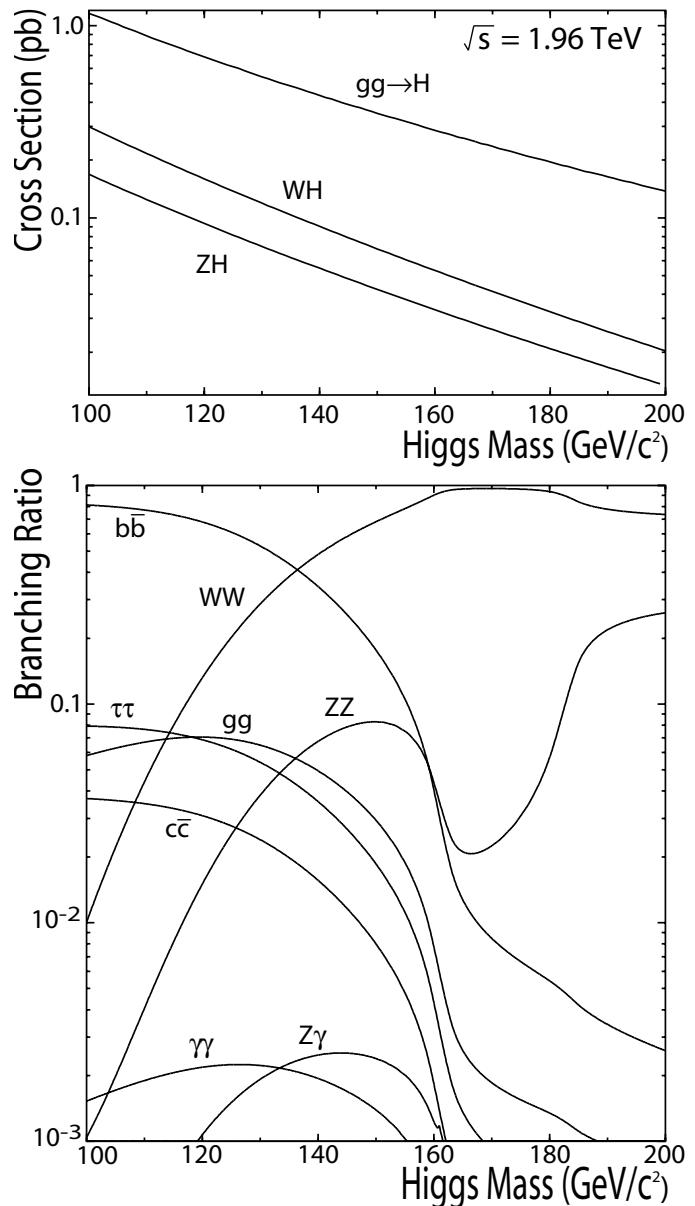


- Dominant decay depends on m_H :
 - for $m_H \leq 135 \text{ GeV}$ is $H \rightarrow b\bar{b}$.
 - for $m_H \geq 135 \text{ GeV}$ is $H \rightarrow WW$.

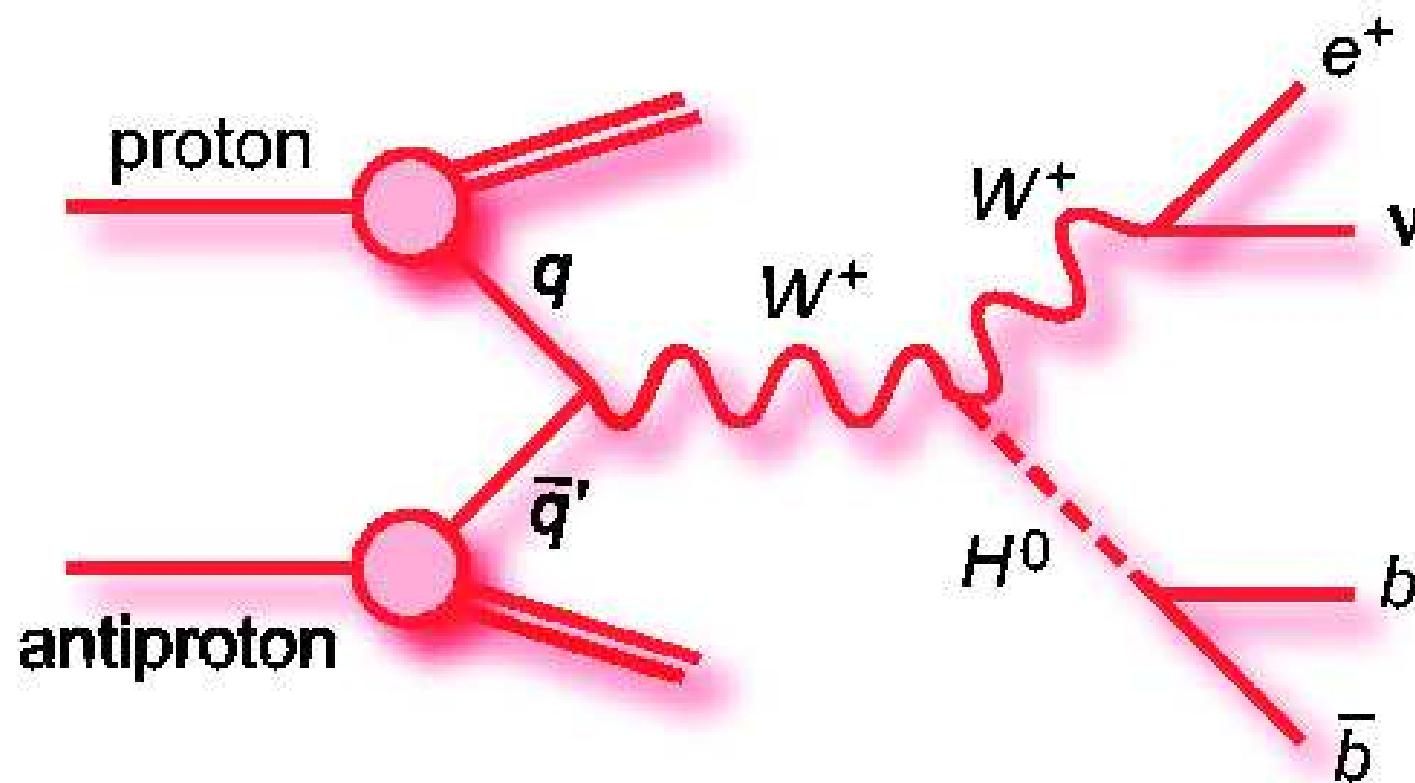


Search Strategy

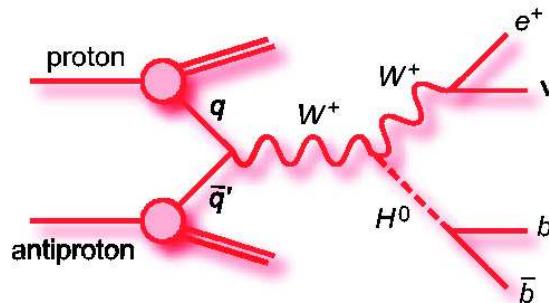
- Given the low cross sections, the strategy is driven by the dominant decay mode.
- For $m_H \leq 135$ GeV:
 - $H \rightarrow b\bar{b}$ dominant decay \Rightarrow Need efficient b -tagging algorithms.
 - $gg \rightarrow H$ production not viable (overwhelmed by QCD background) \Rightarrow use associated production.
 - W/Z reconstructed in leptonic decay.
- For $m_H \geq 135$ GeV:
 - Leptonic W decays provide clean final states.
 - Exploit gluon-gluon fusion production.
- Both CDF and DØ are covering as many search channels as possible and combining the results.



WH Signal: Lepton + Jets Sample

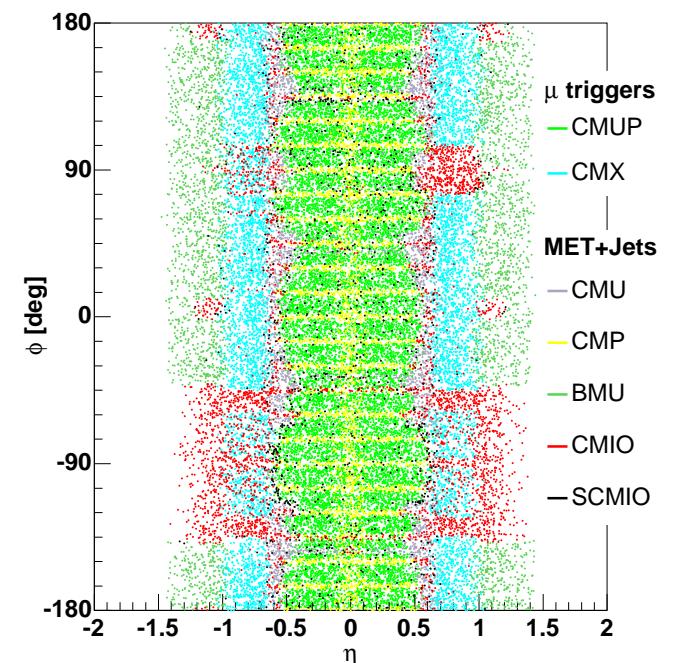
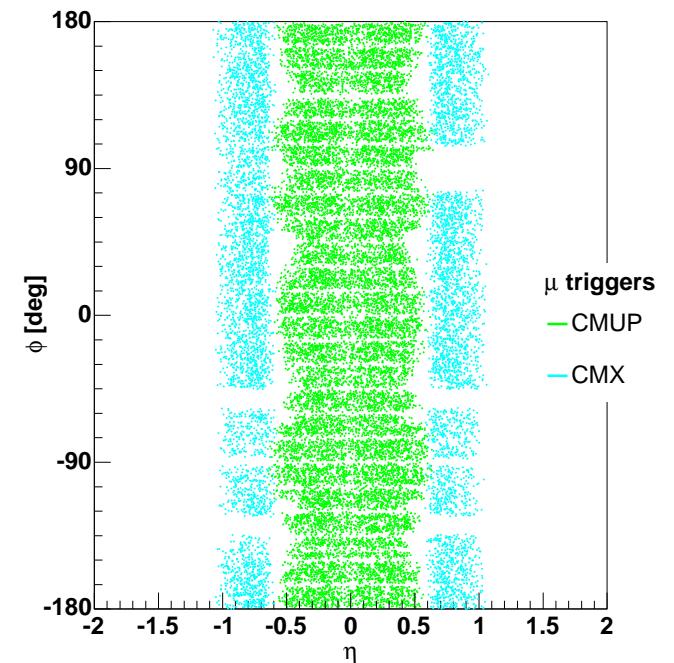


WH Event Selection



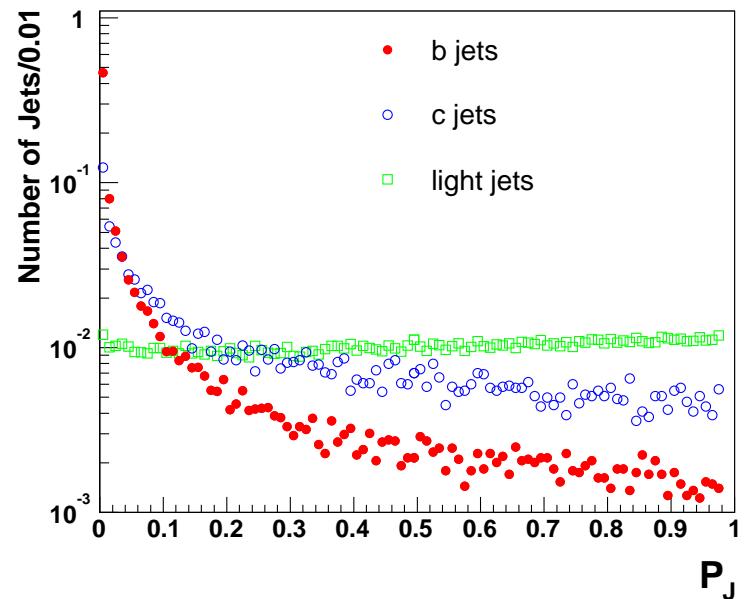
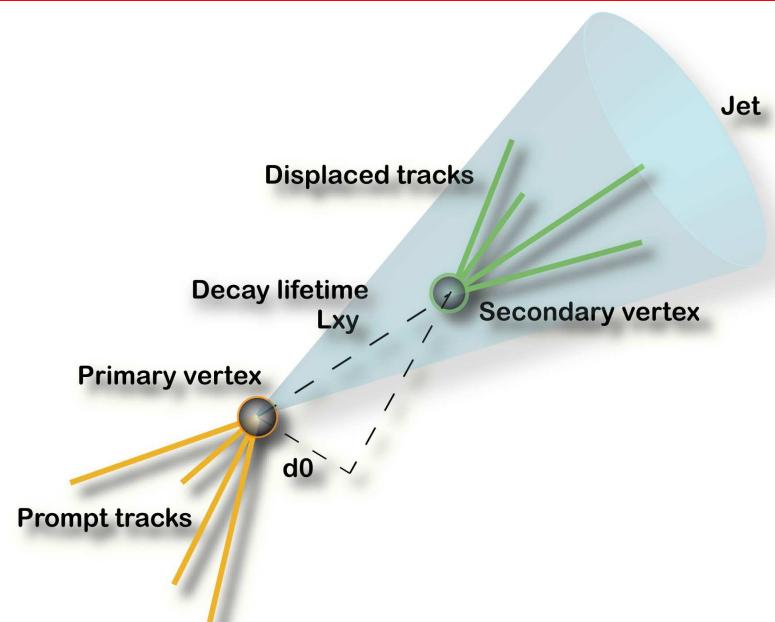
High p_T lepton triggers

- High p_T isolated lepton (e/μ): $p_T > 20$ GeV.
 - ◊ Extended muon coverage (recovering leptons from the “cracks” using MET+jets trigger).
 - ◊ Acceptance gain of $\sim 15\%$.
- High missing transverse energy: $\cancel{E}_T > 20$ GeV ($\cancel{E}_T > 25$ GeV for forward electrons).
- Two or three jets:
 - ◊ $E_T > 20$ GeV.
 - ◊ $|\eta| < 2.0$
- At least one jet identified as a b-jet.



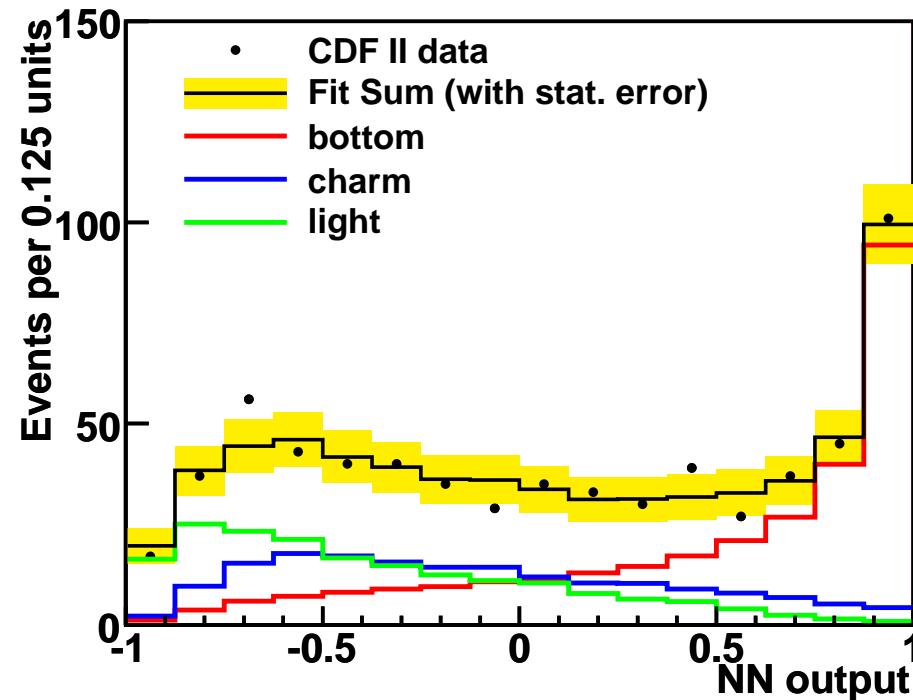
b-tagging

- To identify a b-jet we exploit the peculiarities of B mesons: long lifetime, high mass, presence of soft leptons.
- Two Standard CDF b-tagging algorithms:
 - ◊ **SecVtx (SV)**: Reconstruction of secondary vertices displaced from the interaction point.
 - ◊ **JetProbability (JP)**: Track-based probability for the jet to originate from the interaction point ($\text{JP} < 5\%$).
- Using these taggers we split the sample in 3 independent categories :
 - ◊ **SVSV**: SecVtx + SecVtx
 - ◊ **SVJP**: SecVtx + JetProb
 - ◊ **SVnoJP**: SecVtx
- This improves the sensitivity by $\sim 8\%$ wrt using 2 categories (SVSV, SV).



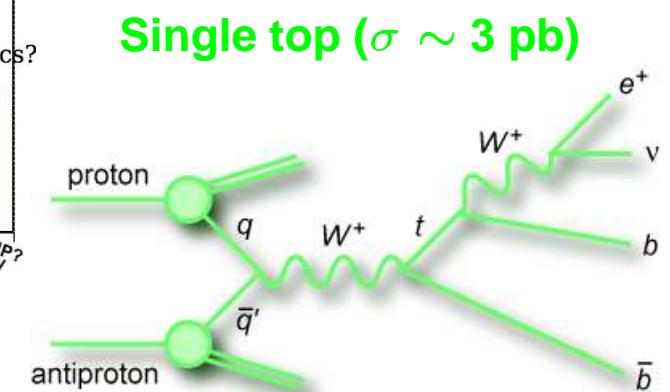
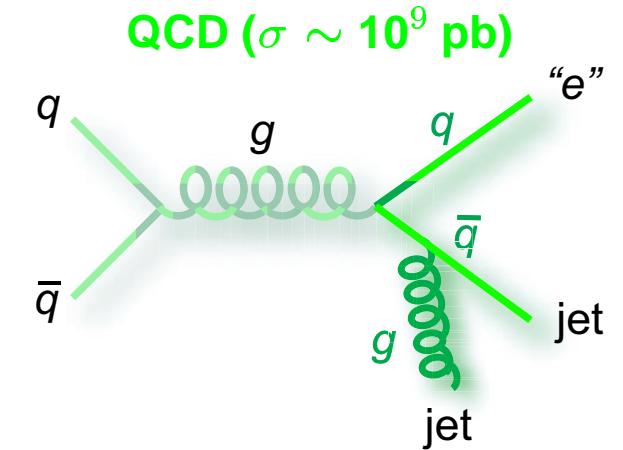
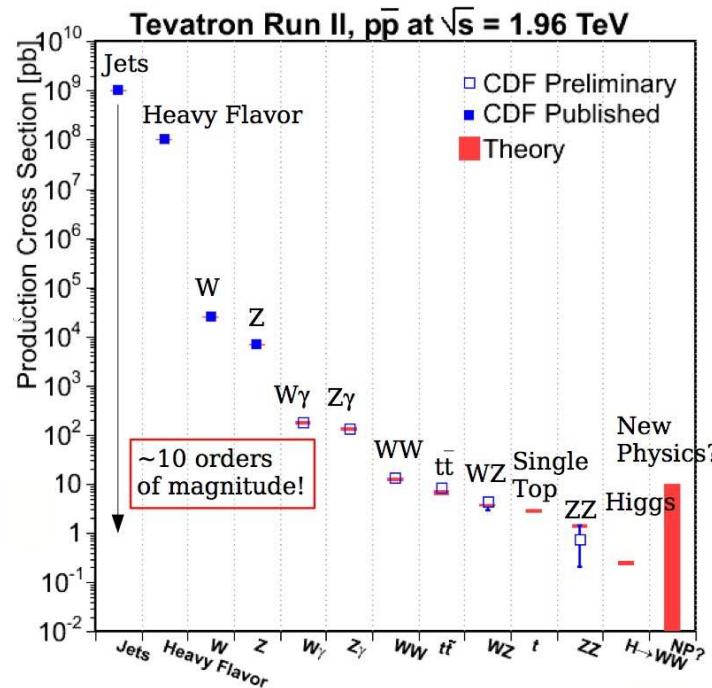
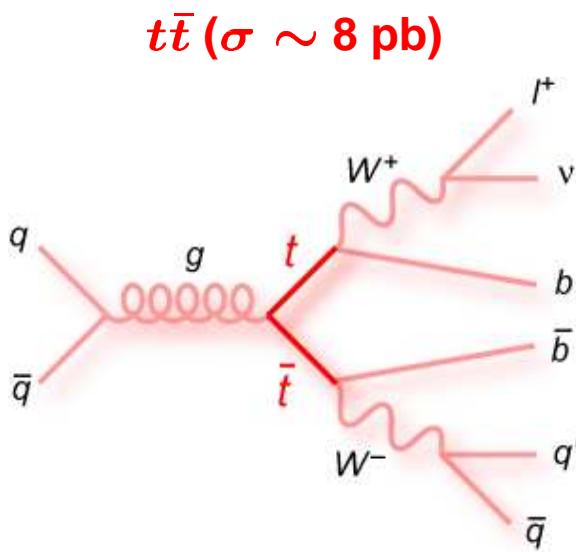
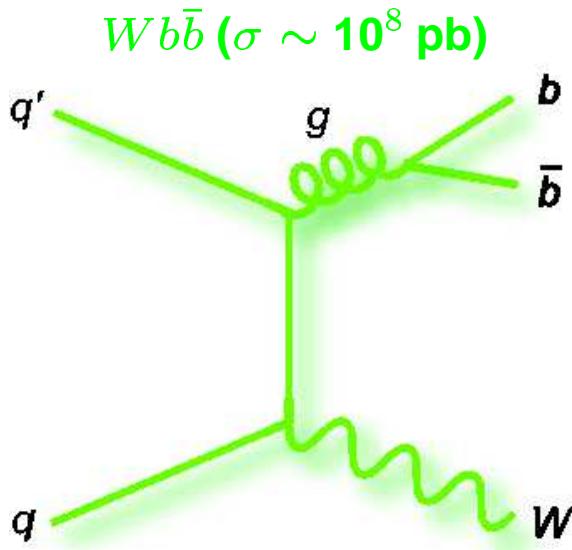
Neural Network Flavor Separator

- After applying b-tagging, 50% of the background in the lepton+jets sample do not contain b quarks.
- NN to separate jets from **b-quark** from **c-quark** and **light-quark** jets.
- Trained with jet and track variables (vertex mass, decay length, track multiplicity...).



- Improved the single top search sensitivity by 10-20%!!!
- This variable is used as a weight per event in this analysis.

Lepton + Jets Signature: Main Backgrounds



Background Estimation

- **Top/EWK ($t\bar{t}$, s-top, Dibosons/Z+jets):**

MC normalized to theoretical cross-sections

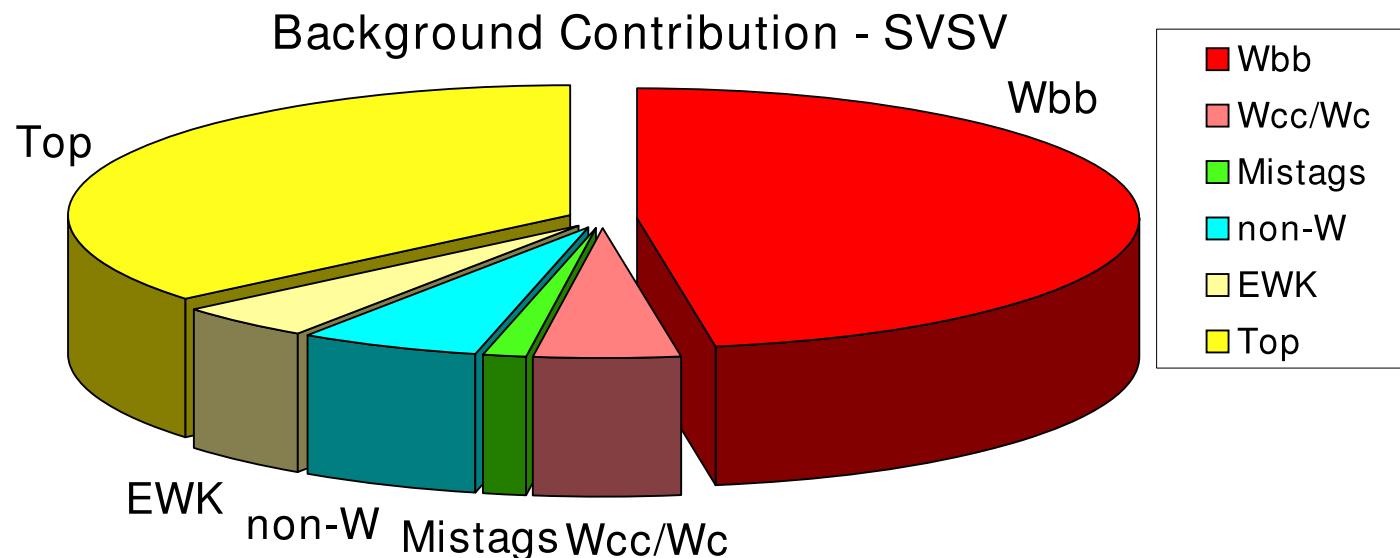
$$N_{p\bar{p} \rightarrow X} = \sigma_{p\bar{p} \rightarrow X} \cdot e_{evt} \cdot e_{tag} \int dt \cdot L$$

- **W+HF ($Wb\bar{b}/Wc\bar{c}/Wc$):**

Largest background contribution

Normalization from data

Heavy flavor factors from ALPGEN MC



- **Non-W:**

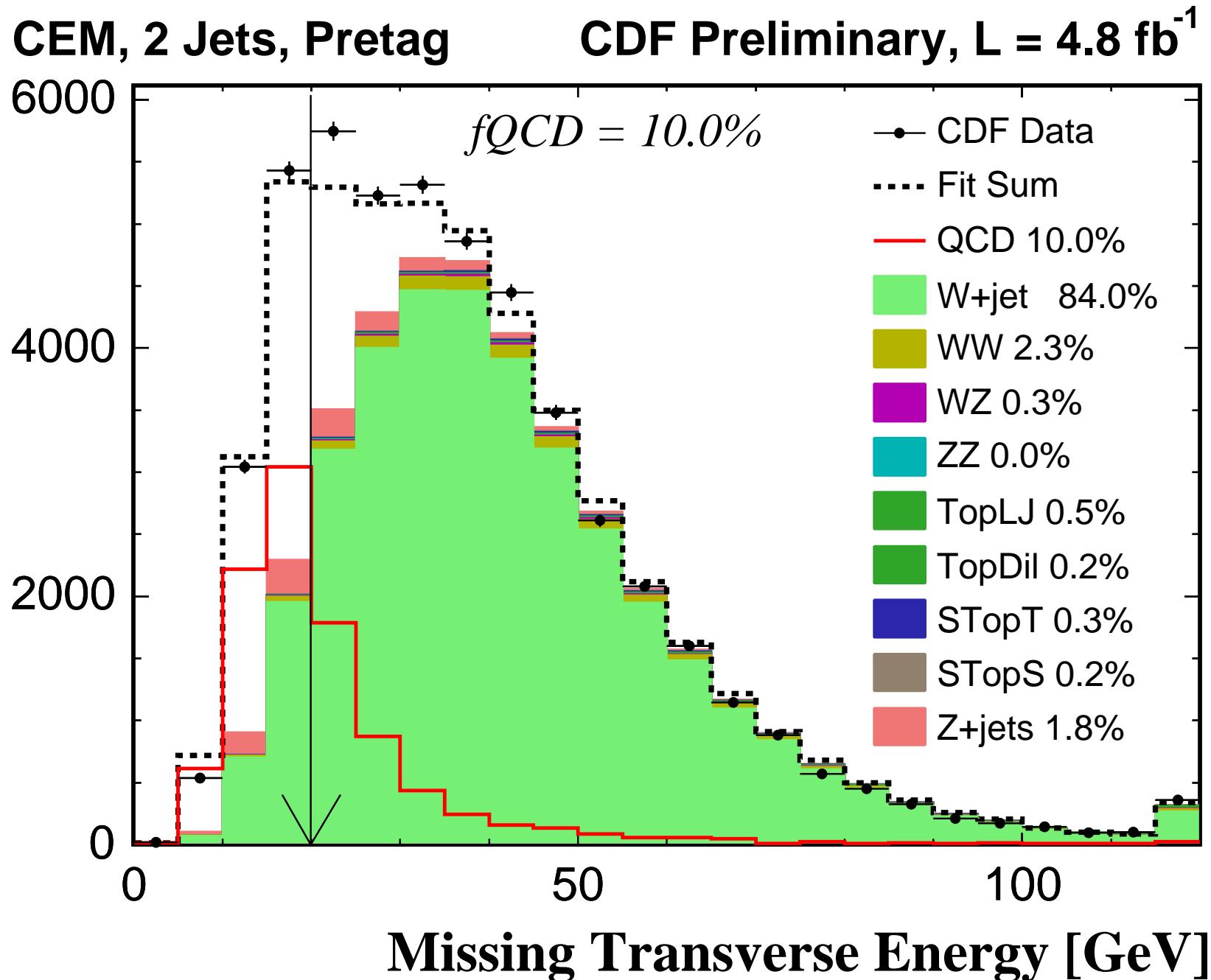
Data-driven method

Fit the \cancel{E}_T distribution in pretag and tagged data

- **Mistags ($Wjj/Wgj/Wgg$):**

Light or gluon jet falsely identify as a HF jet
Mistag probability parameterization obtained from data

non-W Model from Data



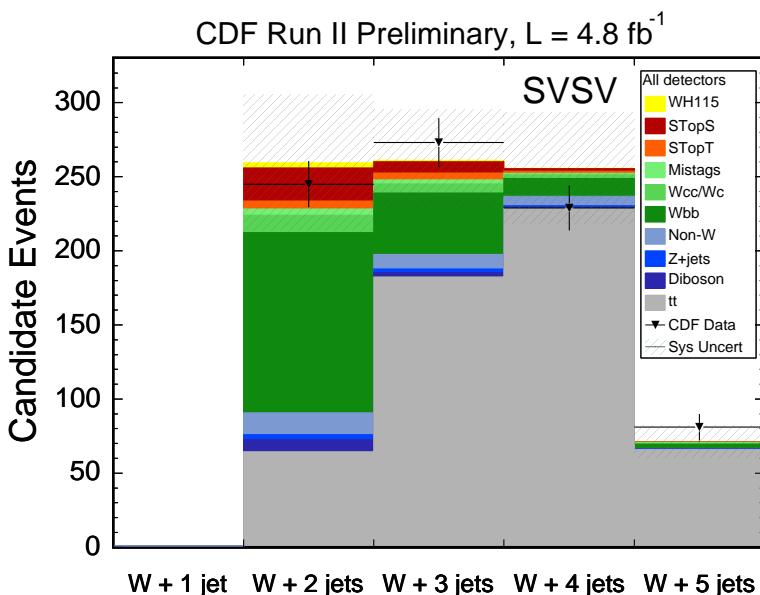
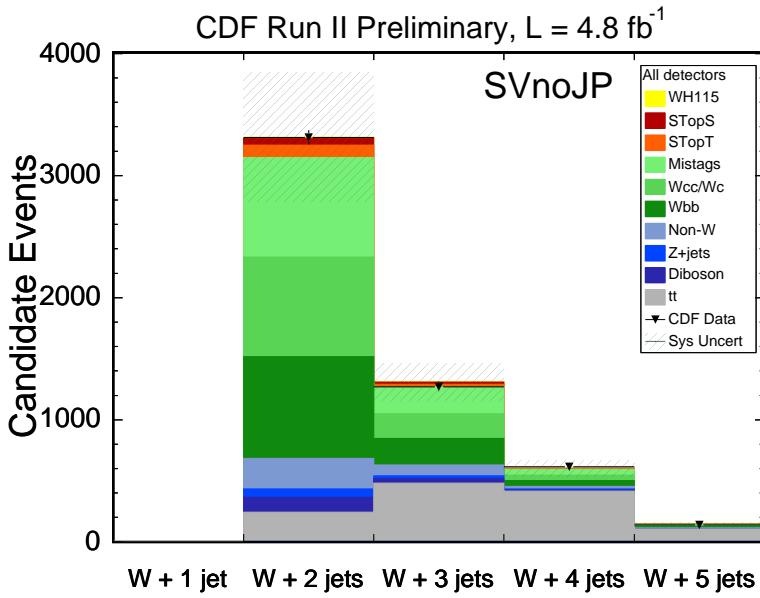
Background Estimate (4.8 fb^{-1})

2 jets			
Process	SVSV	SVJP	SVnoJP
Total MC Based	104 ± 13	83 ± 13	589 ± 51
Wbb	122 ± 39	103 ± 34	835 ± 252
Wcc/Wc	12 ± 4	39 ± 14	818 ± 252
Total HF	134 ± 43	142 ± 47	1653 ± 502
Mistags	4 ± 1	16 ± 9	819 ± 119
Non-W	15 ± 6	26 ± 10	250 ± 100
Total Prediction	257 ± 45	267 ± 52	3311 ± 528
WH115	3.47 ± 0.41	2.39 ± 0.30	8.79 ± 0.69
Observed	245	263	3313

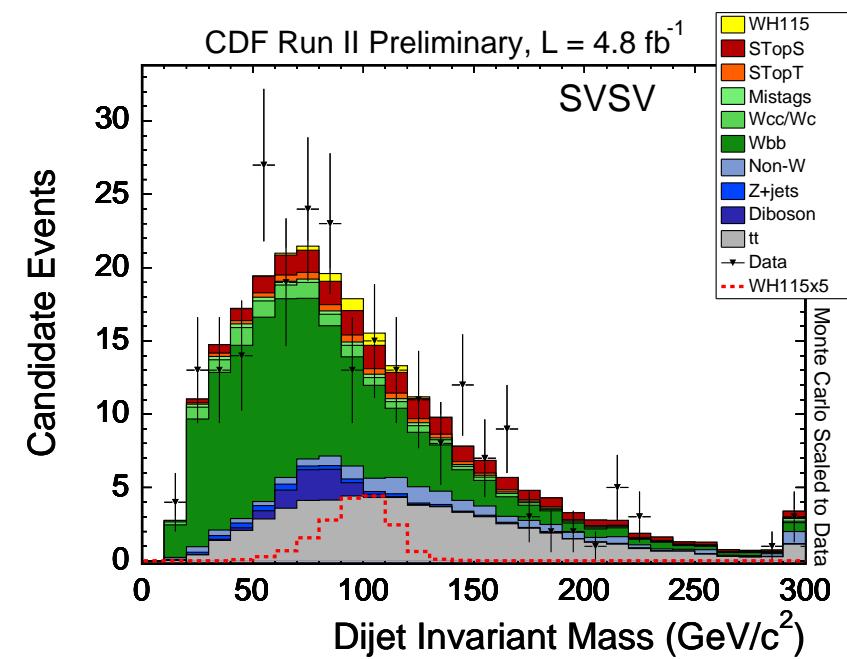
Background Estimate (4.8 fb^{-1})

3 jets			
Process	SVSV	SVJP	SVnoJP
Total MC Based	200 ± 30	171 ± 29	581 ± 65
Wbb	42 ± 14	41 ± 14	221 ± 67
Wcc/Wc	6 ± 2	20 ± 7	202 ± 63
Total HF	48 ± 16	61 ± 20	423 ± 128
Mistags	3 ± 1	10 ± 5	221 ± 33
Non-W	10 ± 4	18 ± 7	87 ± 35
Total Prediction	261 ± 34	260 ± 36	1312 ± 151
WH115	0.99 ± 0.12	0.73 ± 0.10	2.20 ± 0.18
Observed	273	267	1271

Experimental Challenge

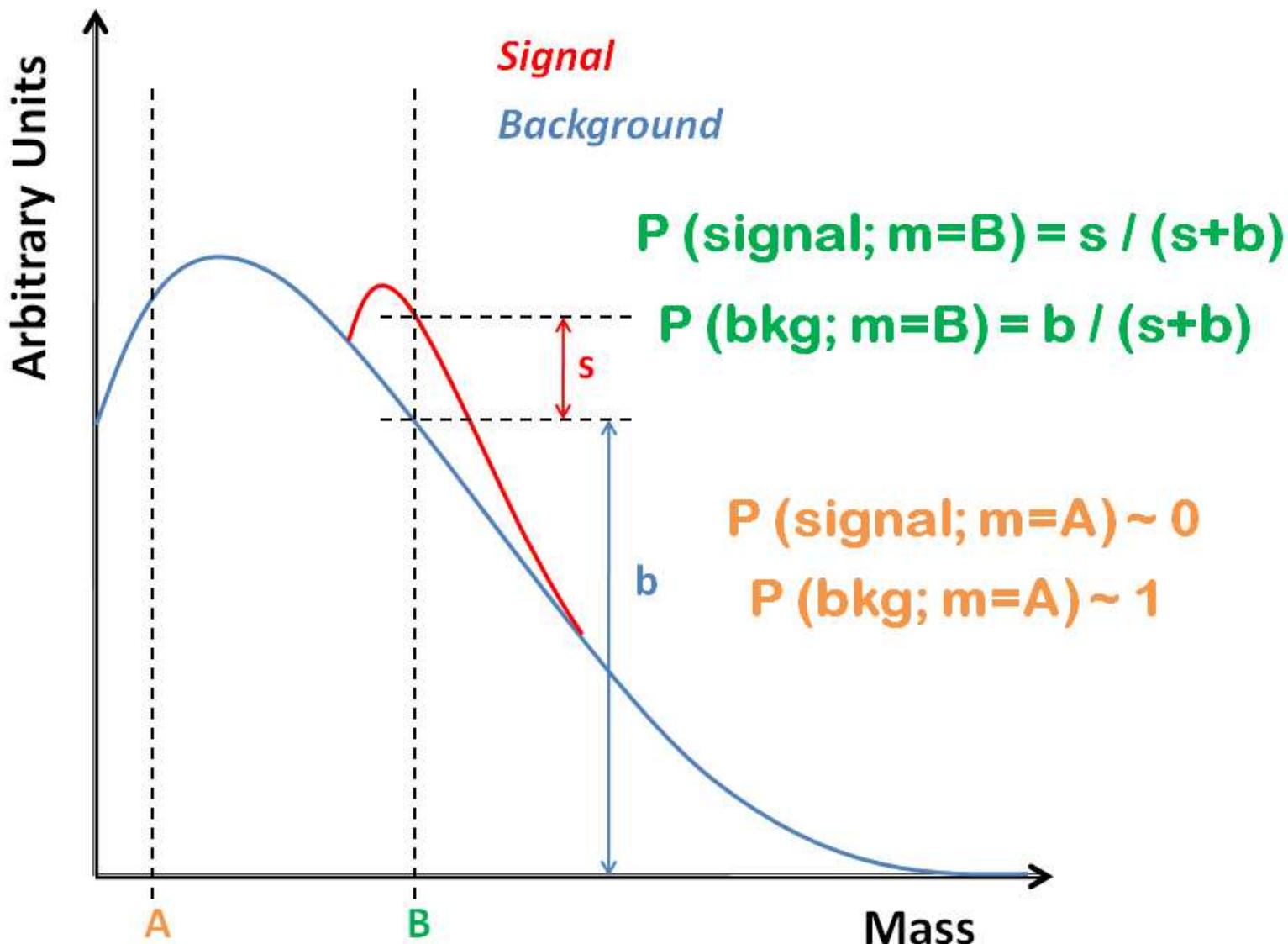


- Signal events even smaller than the uncertainty in the background prediction.
 - Counting experiments are hopeless.
- A single variable is **not enough** to distinguish signal from background.
 - Need sophisticated tools to isolate regions with high signal purity.



Matrix Element Method

- We use a Matrix Element (ME) Technique to calculate event probabilities for the signal and the background (bkg) hypotheses.



Matrix Element Method

- We use a Matrix Element (ME) Technique to calculate event probabilities for the signal and the background (bkg) hypotheses.
- Start from Fermi's Golden rule:

$$P_{evt} = \frac{d\sigma}{\sigma} = \frac{1}{\sigma} |M|^2 d\Phi$$

- But we need to consider:
 - ◊ Parton distribution functions (PDFs): interactions are initiated by partons inside the p and \bar{p} .
 - ◊ Neutrinos in the final state are not identified directly.
 - ◊ The energy resolution of the detector can't be ignored.
- Sum over all possible particle variables (y) leading to the observed variables (x).

$$P_{evt} = \frac{1}{\sigma} \int d\sigma(y) dq_1 dq_2 f(x_1) f(x_2) W(y, x)$$

- $f(x_i)$ are the PDFs with $xi = \frac{E_{q_i}}{E_{beam}}$ and $W(y, x)$ is the transfer function (TF).
- The TF correct for jet energy resolution, hadronization, detector effects,...

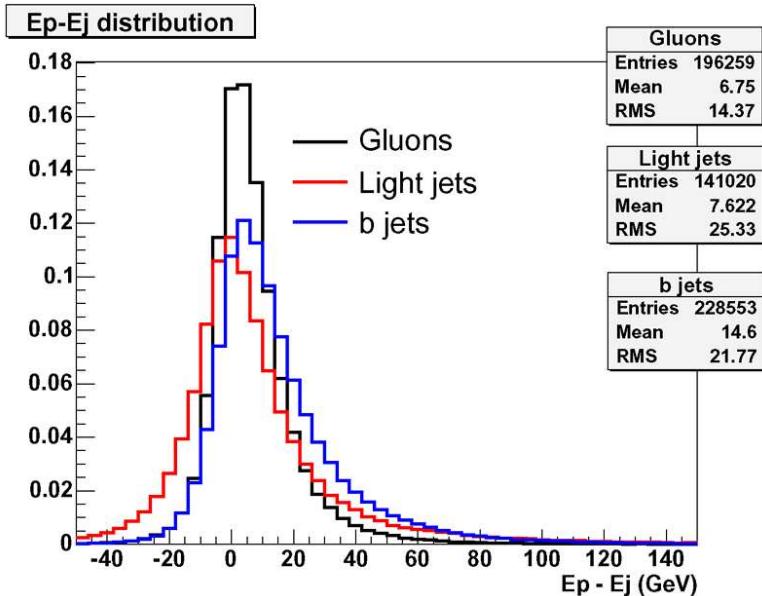
Transfer Function for Jet Energies

- The transfer function is given by:

$$W(y, x) = \delta^3(p_l^y - p_l^x) \delta^2(\Omega^y - \Omega^x) W_{jet}(E_{parton}, E_{jet})$$

- Since the lepton and jet angles are well measured:

$$W(y, x) = W_{jet}(E_{parton}, E_{jet})$$



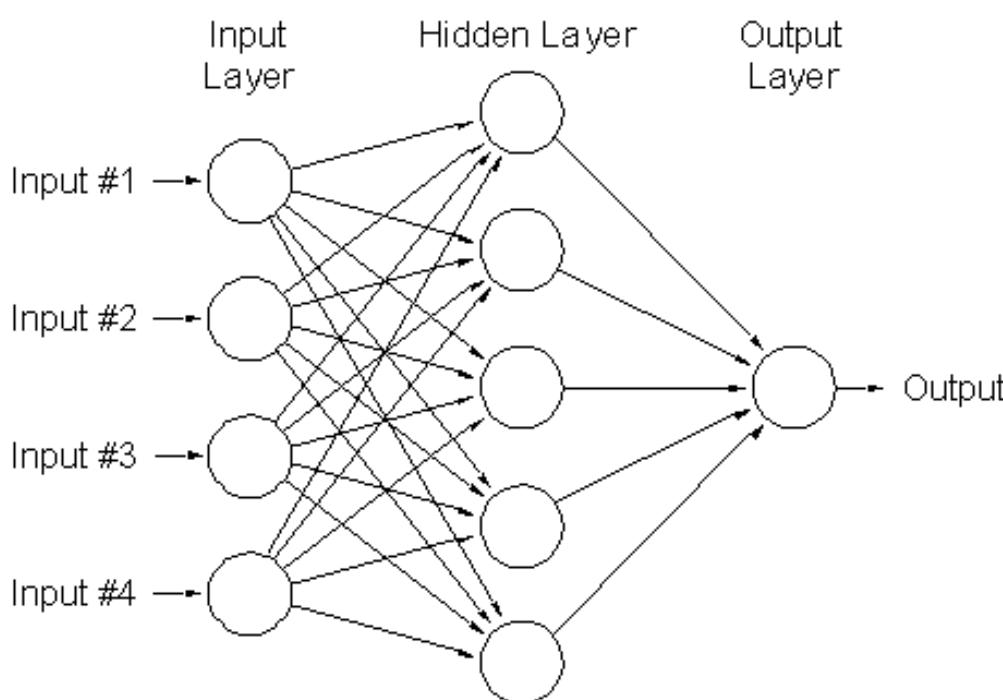
- Mapping between parton and jet energies:
 $\delta_E = E_{parton} - E_{jet}$
- We parameterize the δ_E distribution as a sum of two Gaussian functions:
 - One to account for the peak.
 - Other to account for the asymmetric tail.

- Transfer Function (TF):

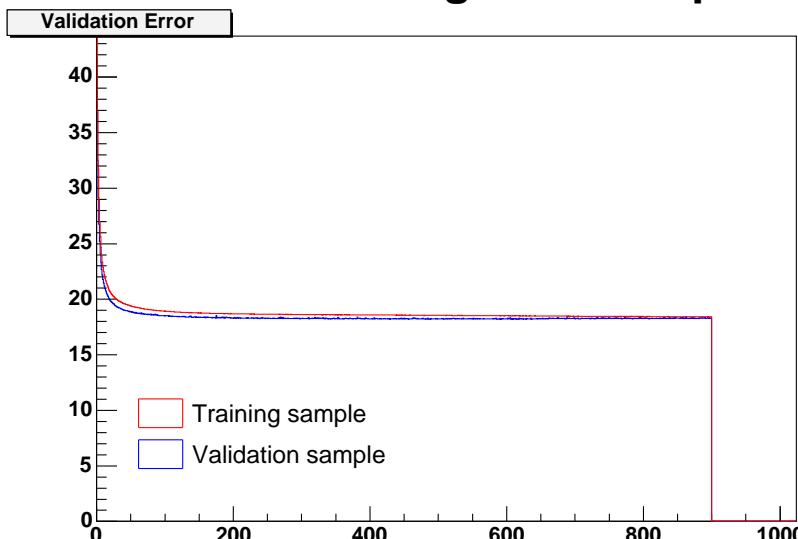
$$W_{jet}(E_{parton}, E_{jet}) = \frac{1}{\sqrt{2\pi}(p_2 + p_3 p_5)} \left(\exp \frac{-(\delta_E - p_1)^2}{2p_2^2} + p_3 \cdot \exp \frac{-(\delta_E - p_4)^2}{2p_5^2} \right)$$

- We wish to improve the transfer functions \Rightarrow use a **Neural Network**.

Neural Network Description



Validation and Training error vs epochs:



- Trained a Neural Network to better reproduce **the parton energy (E_p)**.

- 7 input variables:

- ◊ E cone 04, Sum E , p_T , ϕ , η , Raw E , E cone 07

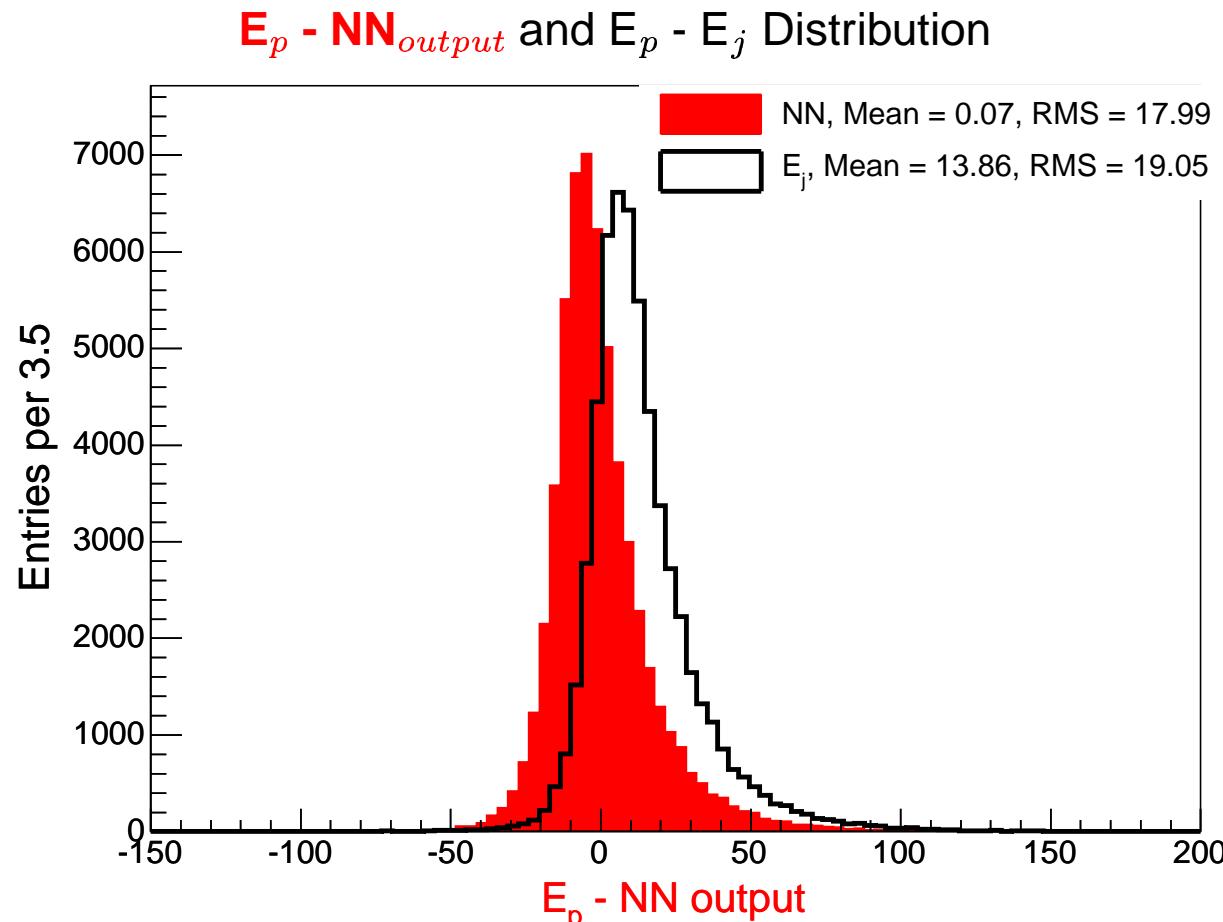
$$\text{SumE} = \sum \frac{p_T \text{ track}}{\sin(\theta)}$$

- 1 hidden layer with 14 hidden nodes.
- Output variable: E_p
- Trained with 900 epochs.

Correlations between the 7 input variables and the output:

#	input name	correl. to output(# 7)
0	E_j	0.98492
6	$EjCone07$	0.98321
5	$RawEj$	0.97254
3	Pt_j	0.72994
2	$SumE$	0.30790
1	$EtaJ$	0.00174
4	Phi_j	0.00147

Example of the Performance of the WH 115 GeV NN

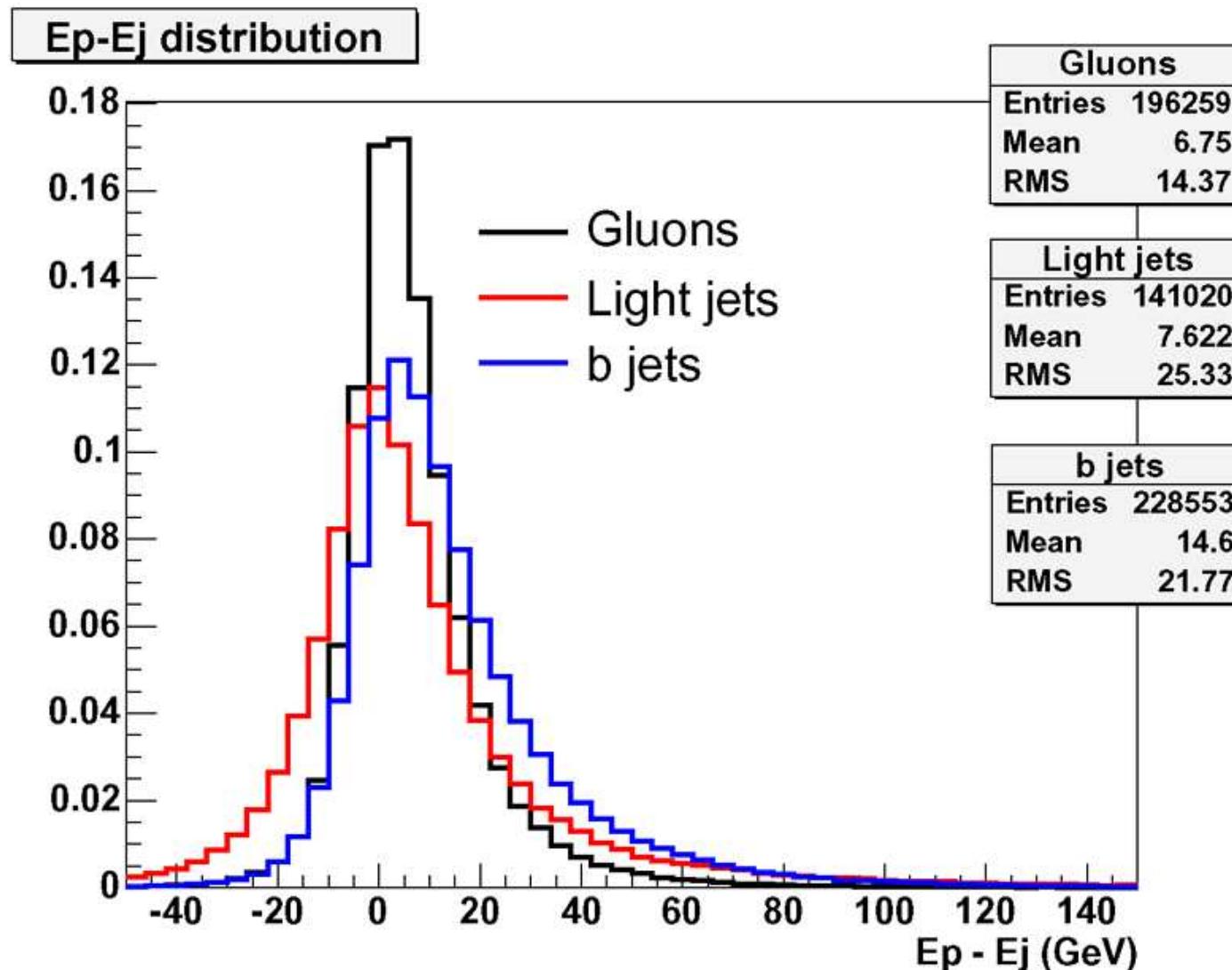


- **Result:**

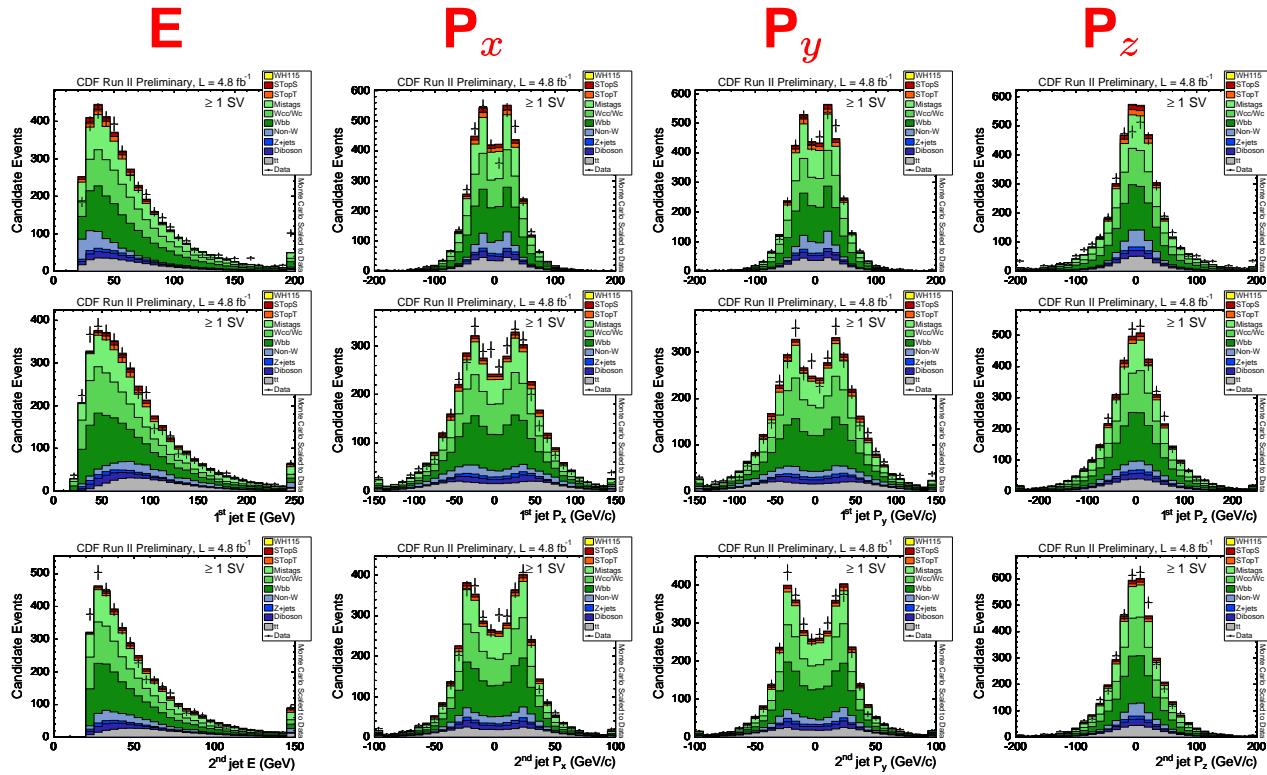
- ◊ $\text{NN}_{\text{output}}$ is closer to E_p than E_j .
- ◊ $E_p - \text{NN}_{\text{output}}$ is narrower than $E_p - E_j$.

Neural Network Transfer Functions

- We build **NN TFs** for b-jets, c-jets, light-jets and gluons.



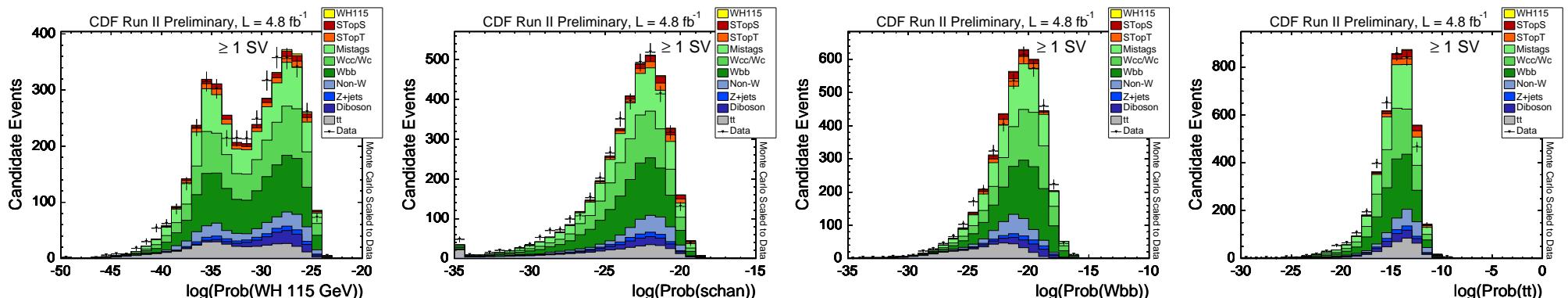
INPUT VARIABLES \Rightarrow PROBABILITIES



$$\frac{1}{\sigma} \int d\sigma(y) dq_1 dq_2 f(x_1) f(x_2) W(y, x) \Rightarrow$$



$$\Leftarrow \frac{1}{\sigma} \int d\sigma(y) dq_1 dq_2 f(x_1) f(x_2) W(y, x)$$



Event Probability Discriminant

- Define ratio of probabilities, obtained with the ME, as Event Probability Discriminant (EPD):
- For SVnoJP and SVJP events:

$$EPD \equiv \frac{b \cdot P_{WH}}{b \cdot (P_{WH} + P_{Wb\bar{b}} + P_{t\bar{t}} + P_{singletop}) + (1-b) \cdot (P_{Wc\bar{c}} + P_{Wcj} + P_{W+light} + P_{Wgg} + P_{dib})}$$

- For SVSV events:

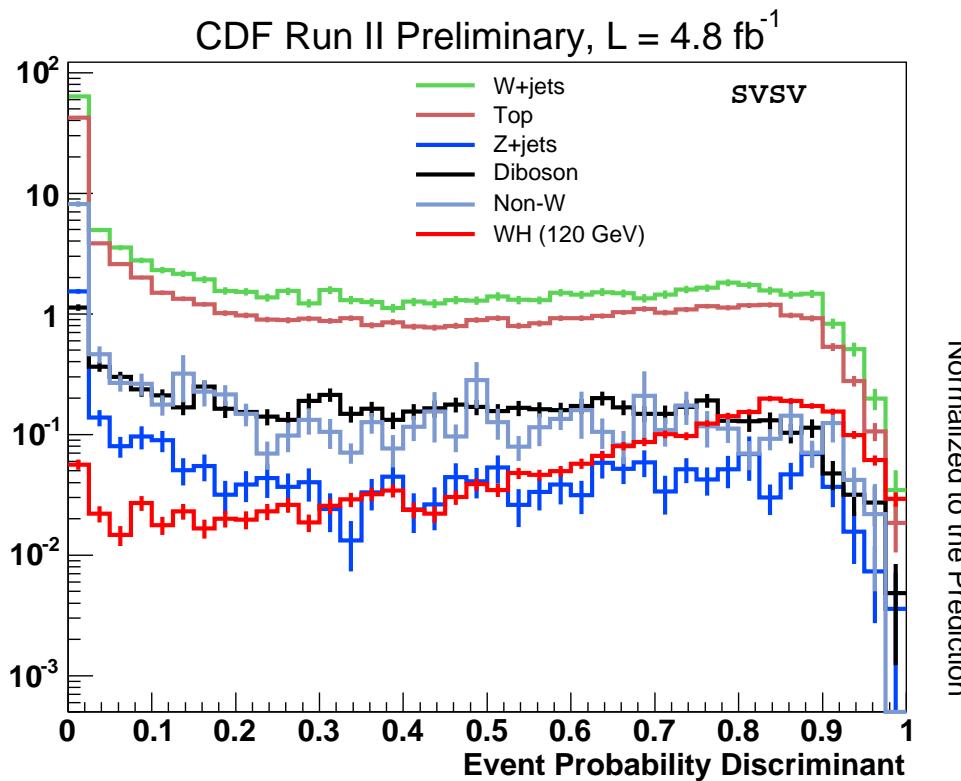
$$EPD \equiv \frac{b_1 \cdot b_2 \cdot P_{WH}}{b_1 \cdot b_2 \cdot (P_{WH} + P_{Wb\bar{b}} + P_{t\bar{t}} + P_{schann}) + b_1 \cdot (1-b_2) \cdot P_{tchan} + (1-b_1) \cdot (1-b_2) \cdot (P_{Wc\bar{c}} + P_{Wcj} + P_{W+l} + P_{Wgg} + P_{dib})}$$

- Where b_i is the NN flavour separator output.
- For 3 jet events, P_{Wcj} , P_{W+l} , P_{dib} are not calculated.
- Each probability has an arbitrary normalization constant which we use to tune the discriminant for optimal sensitivity: the EPD coefficients.

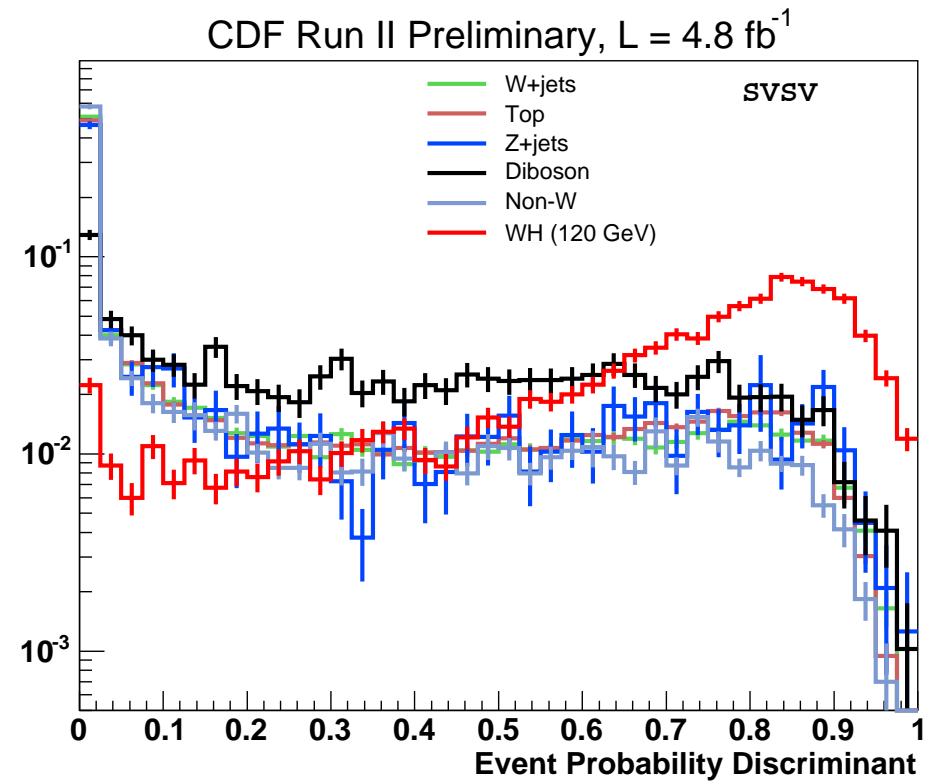
How does the EPD look like?

- Plots show the EPD for the SVSV category in the 2 jet bin.

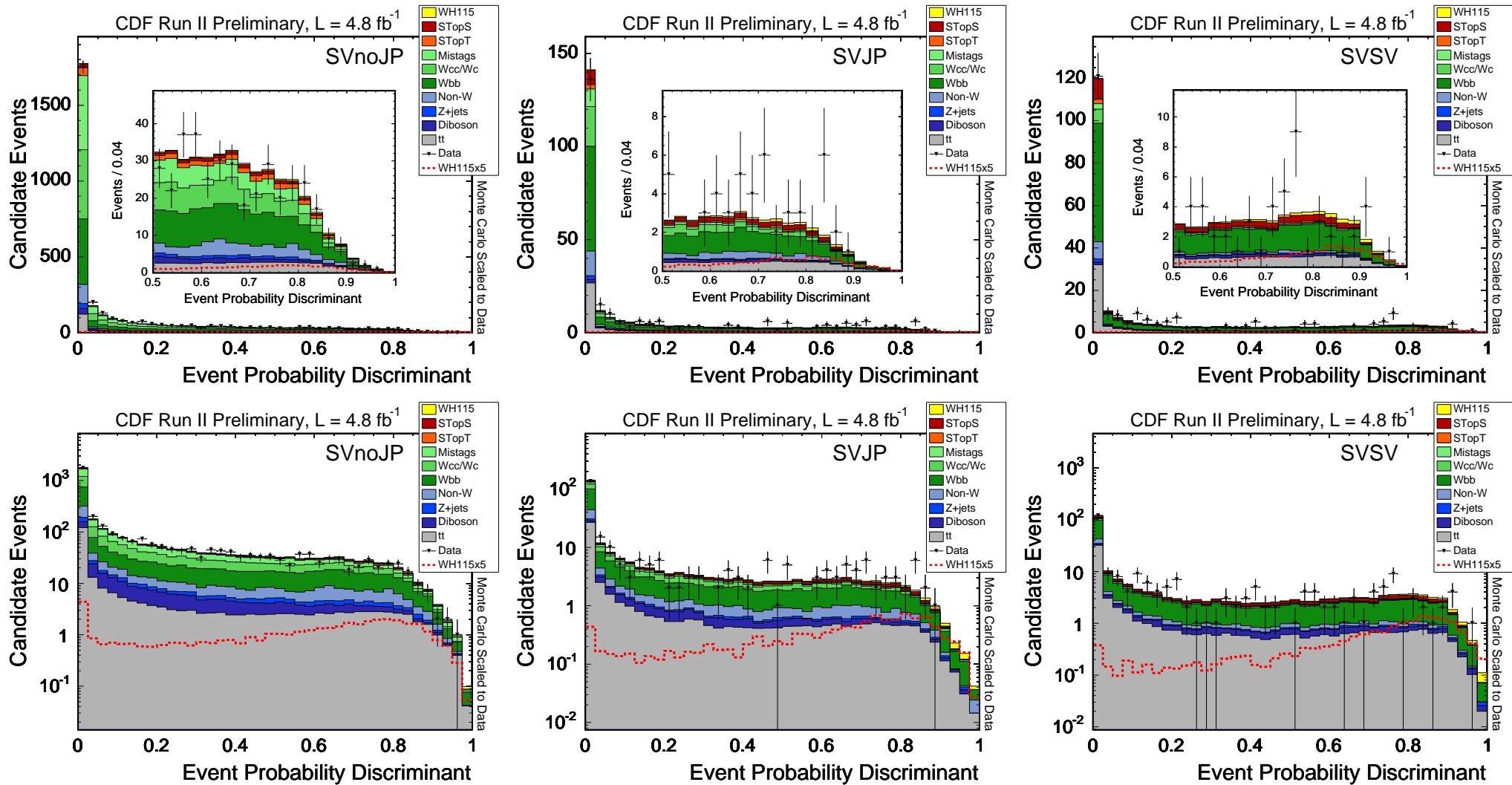
Normalized to the prediction



Normalized to unit area



EPD Distributions (2 jets)



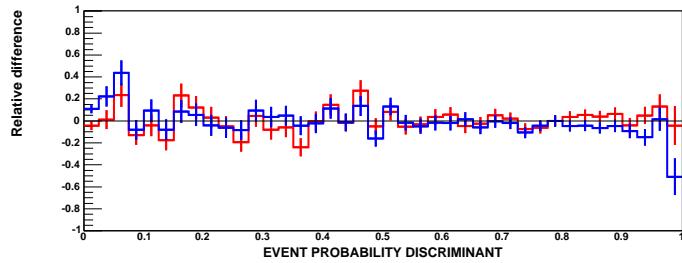
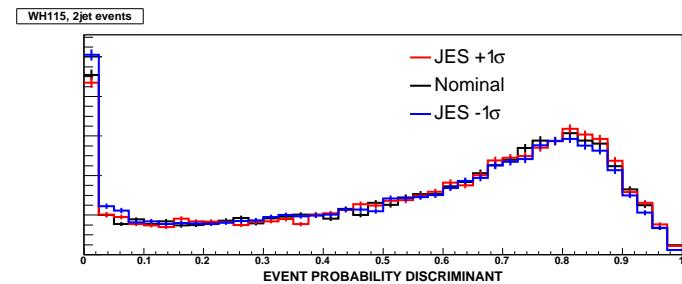
Rate Systematics

- Rate systematics in the three signal regions for the 2 and 3 jet events.
- In brackets are the value when they differ from the 2 jet events.

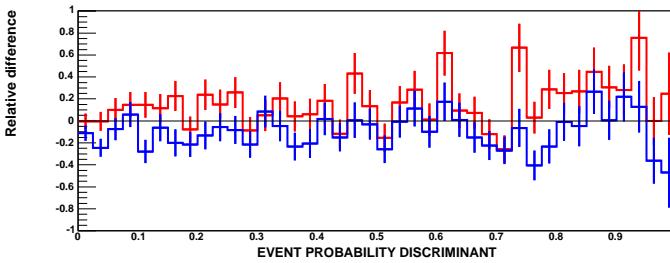
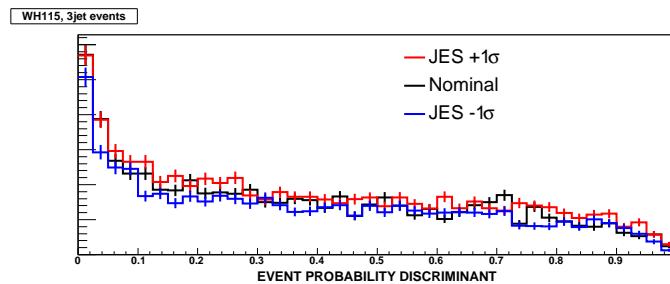
Systematic uncertainty	SVnoJP (%)	SVJP-SVSV (%)
Jet energy scale	2.0 (15.8)	2.0 (13.5)
ISR/FSR + PDF	3.1 (13.1)	5.6 (21.4)
Lepton ID	~2.0	~2.0
Luminosity	6.0	6.0
b-tagging SF	3.5	8.4

JES Shape Systematics

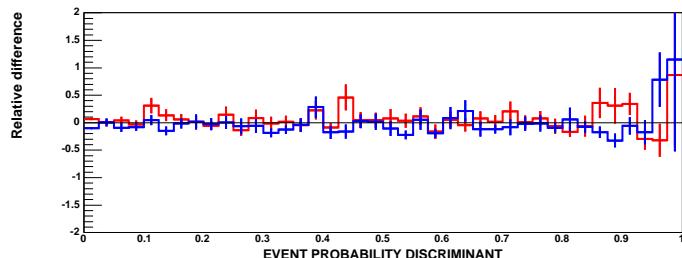
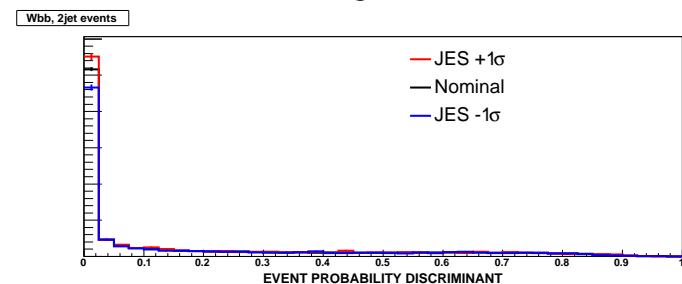
$W H$ 2-jet events



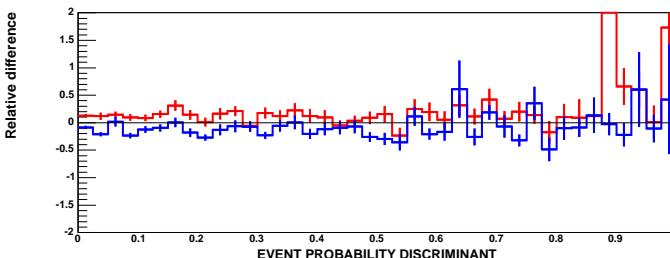
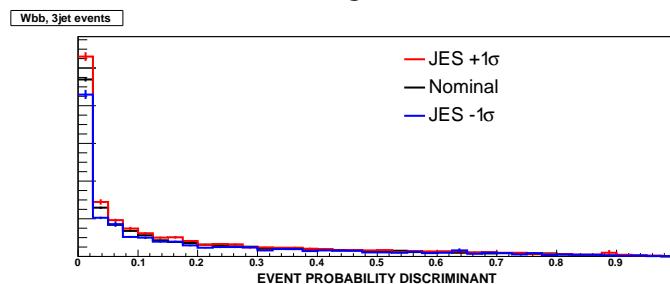
$W H$ 3-jet events



$W b\bar{b}$ 2-jet events



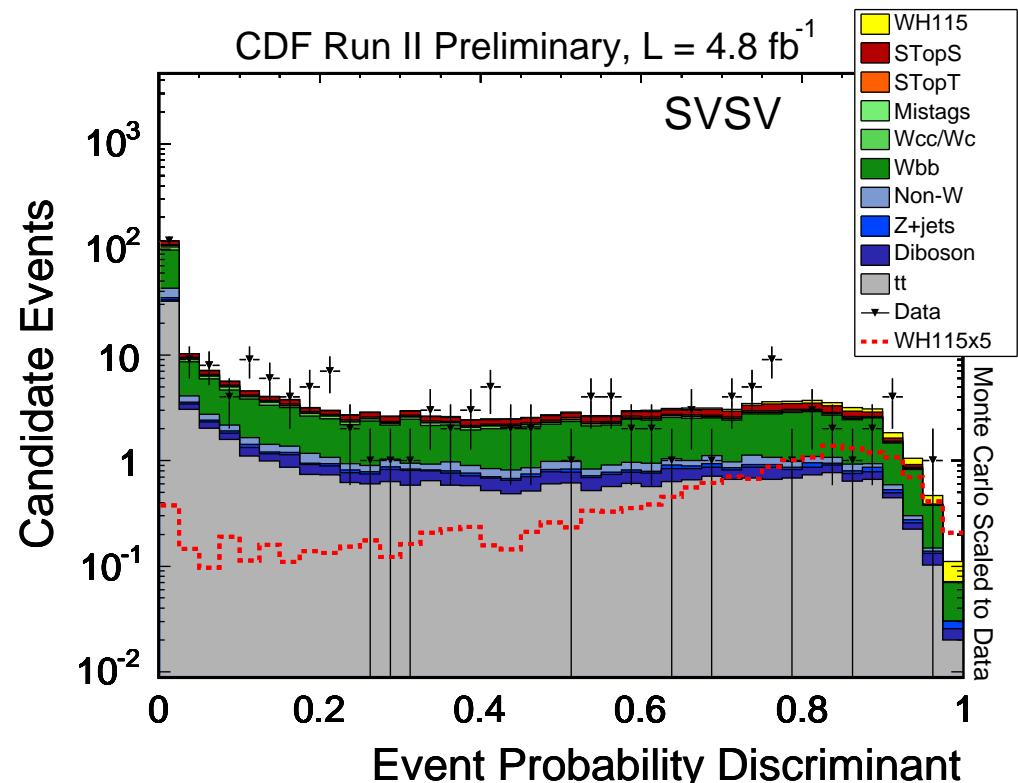
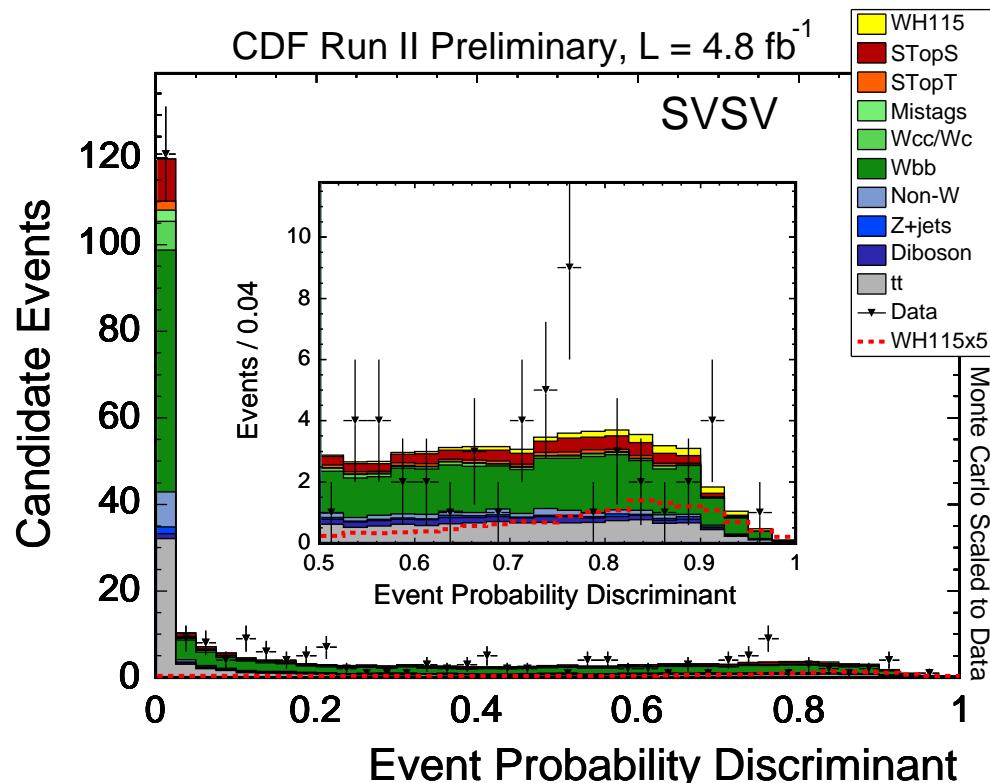
$W b\bar{b}$ 3-jet events



Binned Likelihood Fit

- No excess is observed in the CDF data.
- We set limits for 11 Higgs masses, $100 < m_H < 150$ GeV in 5 GeV steps.
- Likelihood function (per mass):

$$L(\beta_1, \dots, \beta_5; \delta_1, \dots, \delta_{10}) = \prod_{k=1}^B \frac{e^{-\mu_k} \mu_k^{n_k}}{n_k!} \cdot \prod_{j=2}^9 G(\beta_j | 1, \Delta_j) \cdot \prod_{i=1}^{10} G(\delta_i, 0, 1)$$

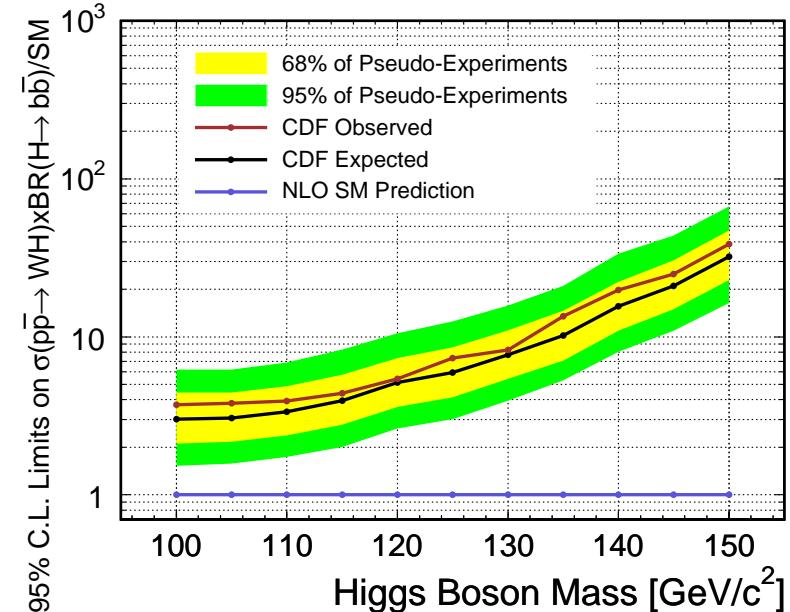


Expected & Observed Limits

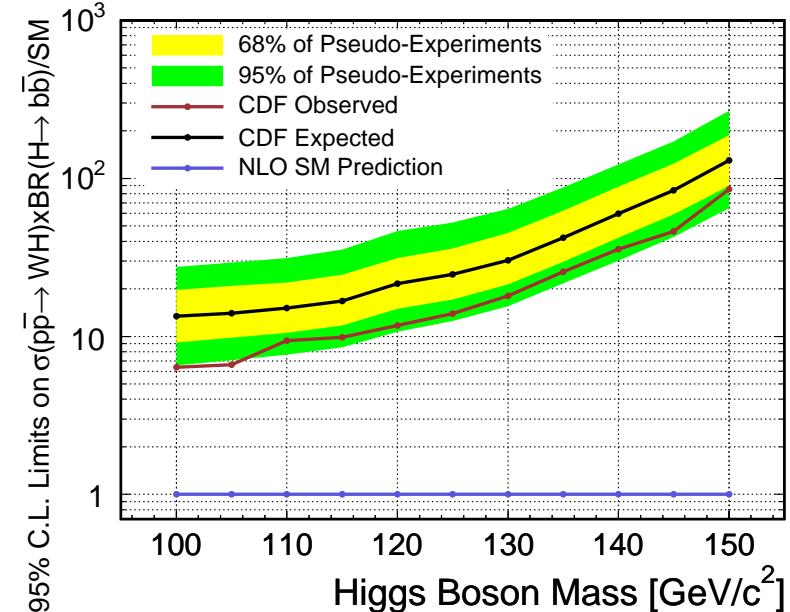
2 jets		
$m_H = 115 \text{ GeV}$	Expected	Observed
SVSV	5.8	-
SVJP	7.8	-
SVnoJP	8.1	-
ALL	3.9	4.4

3 jets		
$m_H = 115 \text{ GeV}$	Expected	Observed
SVSV	24.1	-
SVJP	36.1	-
SVnoJP	36.6	-
ALL	16.7	9.8

CDF Run II Preliminary, $L = 4.8 \text{ fb}^{-1}$, 2 jets



CDF Run II Preliminary, $L = 4.8 \text{ fb}^{-1}$, 3 jets

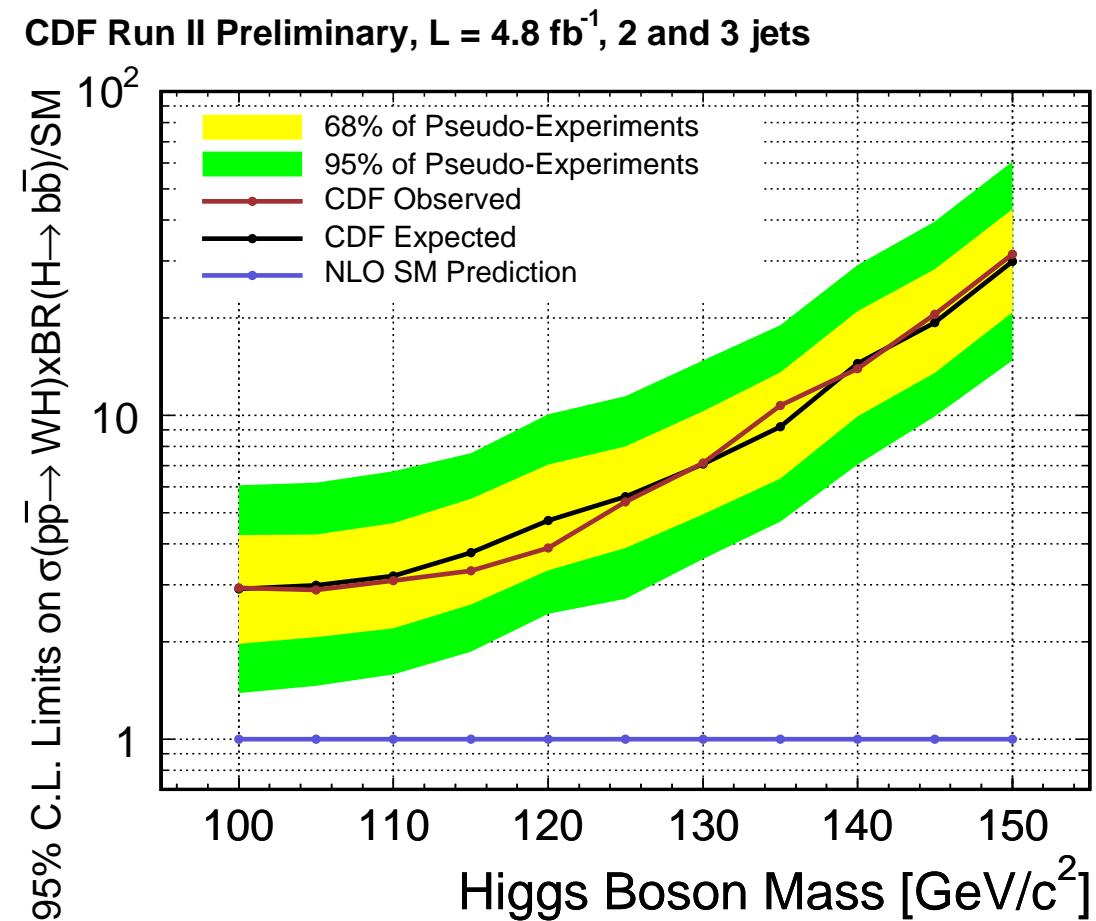


Expected & Observed Limits

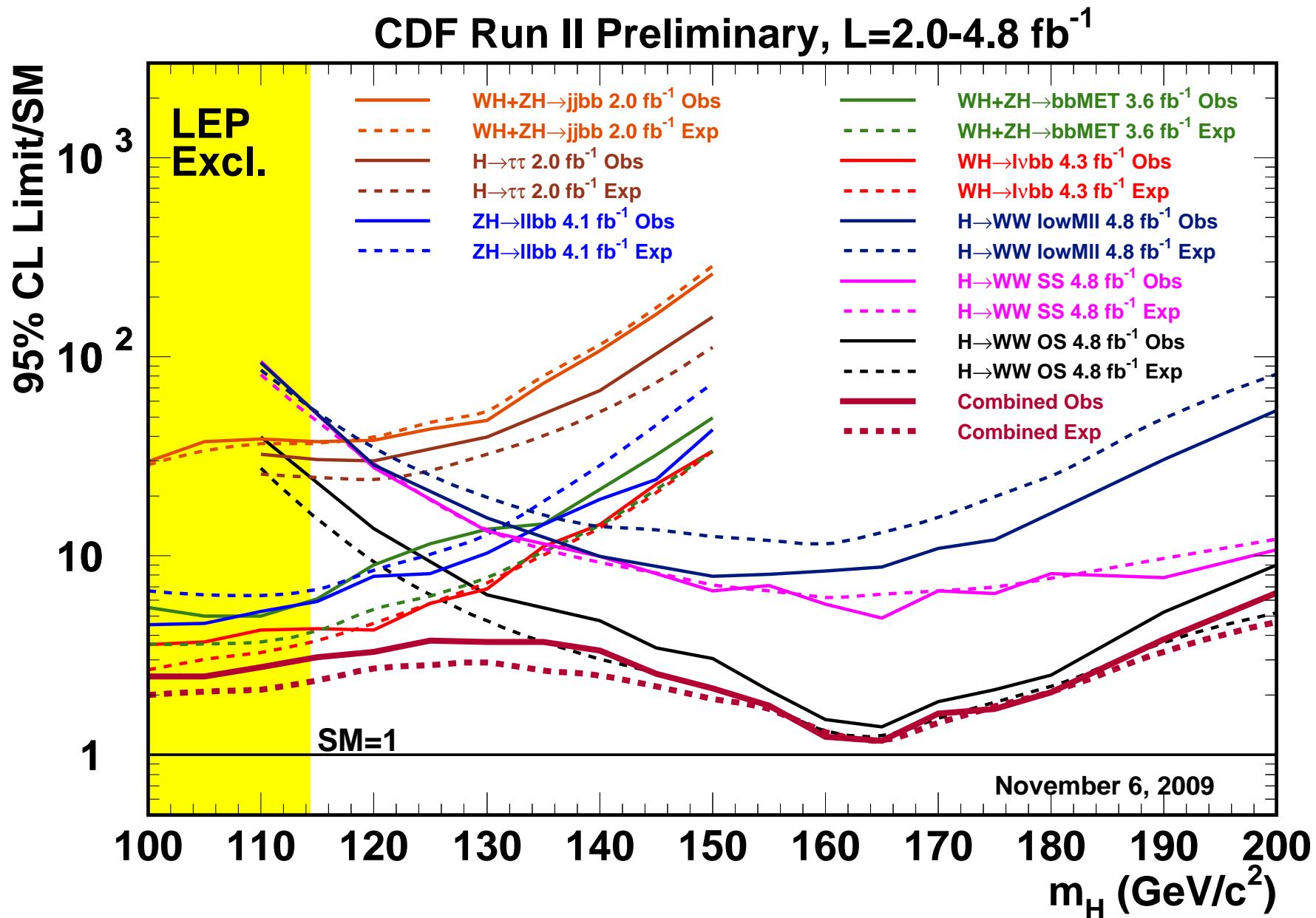
- For 2 and 3 jet events combined together.

2 & 3 jets		
Higgs Mass	Expected	Observed
100	2.9	2.9
105	3.0	2.9
110	3.2	3.1
115	3.8	3.3
120	4.7	3.9
125	5.6	5.4
130	7.1	7.1
135	9.2	10.7
140	14.4	13.9
145	19.3	20.5
150	29.8	31.4

- Including the 3 jet bin improves the sensitivity by **3 to 11%** depending on the mass.

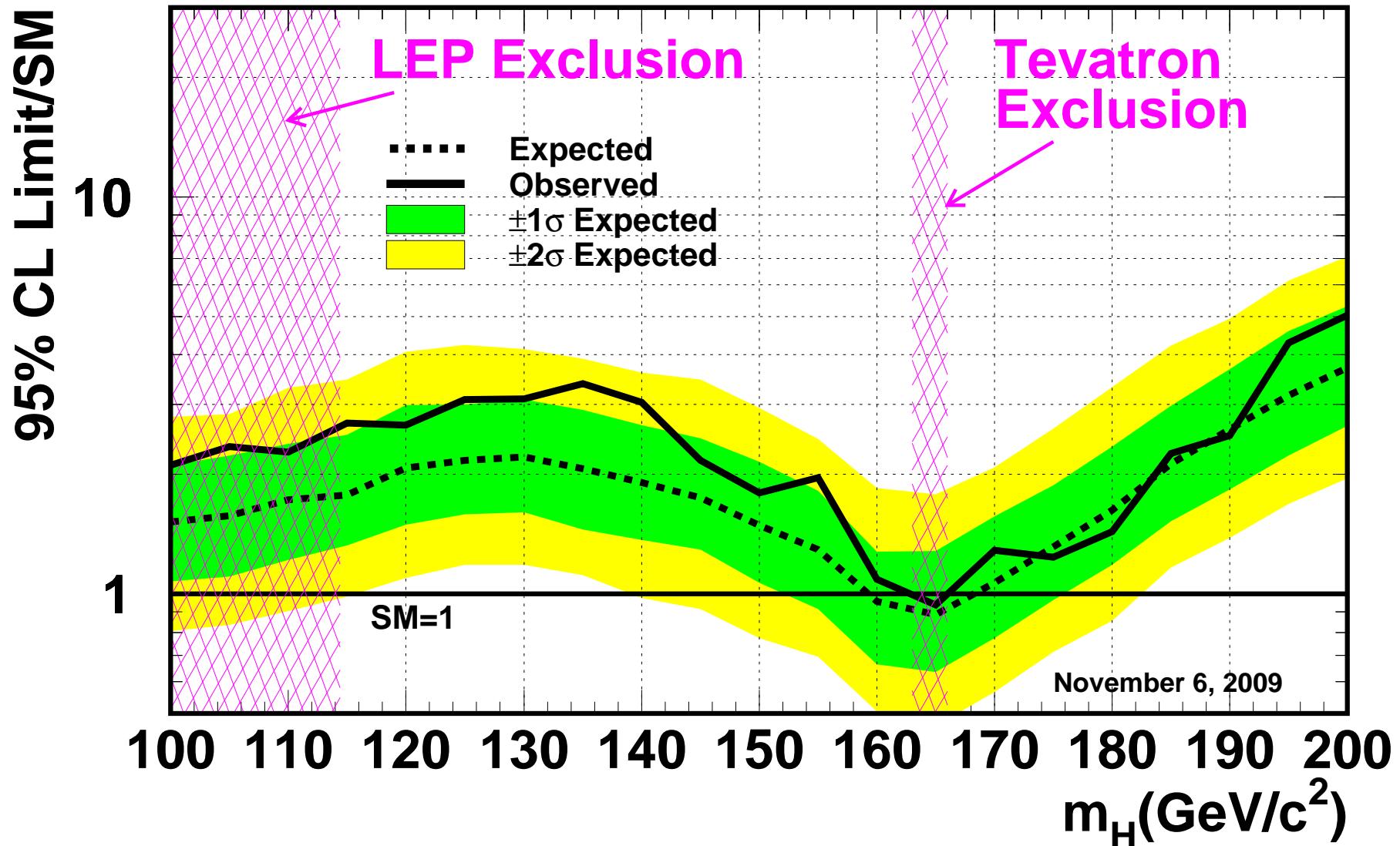


ALL CDF Higgs Searches



Tevatron Combination

Tevatron Run II Preliminary, $L=2.0-5.4 \text{ fb}^{-1}$

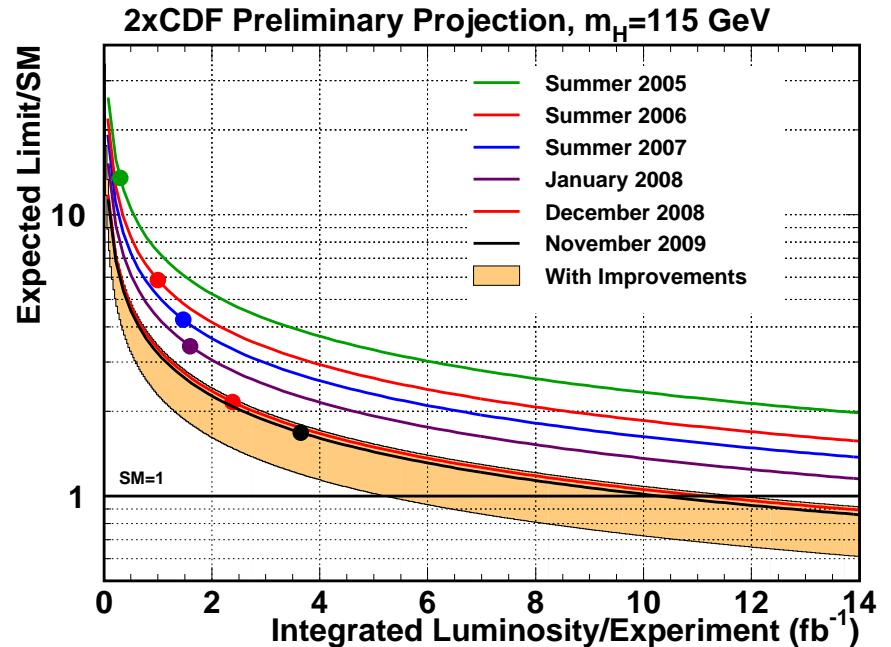


Summary

- Tevatron is performing very well.
- Both experiments are running great, taking data with very high efficiency.
- I have presented the search for the SM Higgs boson associated with a W boson using the ME method with **4.8 fb⁻¹** of CDF II data.
- From the initial result of this analysis many improvements have been applied other than just luminosity:
 - ◊ Increase in acceptance (muons from MET+jets trigger) ($\sim 10\%$).
 - ◊ Splitting in b -tagging categories ($\sim 3\text{-}7\%$).
 - ◊ New Neural Network transfer functions ($\sim 3\%$).
 - ◊ Add the 3 jet bin ($\sim 3\text{-}11\%$).
- For a Higgs mass of 115 GeV the expected (observed) limit is 3.8 (3.3) xSM.

Outlook

- So far, there is no hint of the Higgs boson.
- **Still lots of data to record and analyzed.**
- According to the projections, CDF and DØ **combined** may reach SM sensitivity with $\sim 10 \text{ fb}^{-1}$.
- As of today, **LHC** will run at **7 TeV** until 1 fb^{-1} of data is collected.
- **The race is on!!! Stay tuned!**



THANK YOU!!!

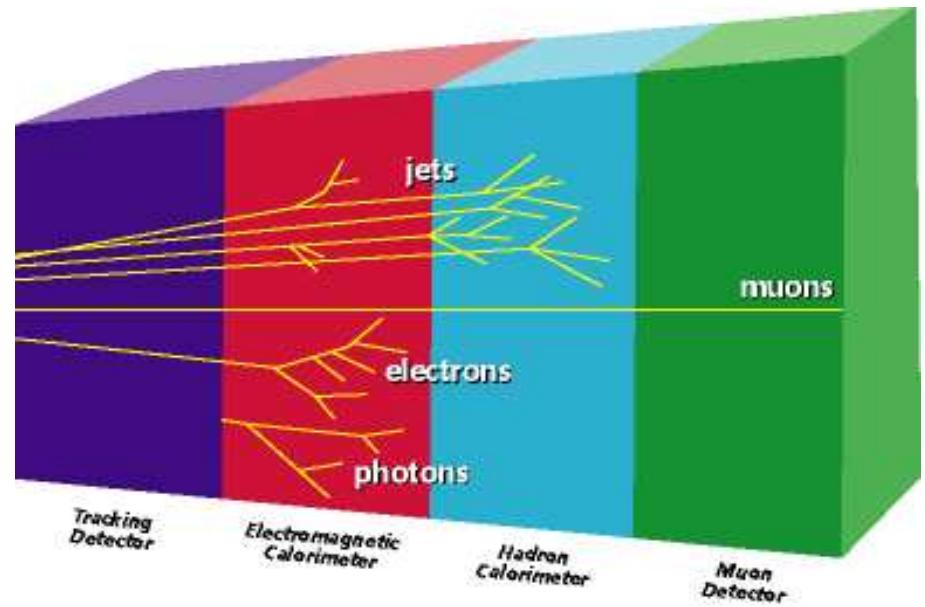
**WHEN THEY FINALLY
DISCOVER THE
HIGGS BOSON
I WANT TO GET
MY PICTURE
TAKEN WITH IT.**



BACK UP SLIDES

Particle identification with tracking and calorimeter

- In calorimeters different particles travel different distances before being absorbed.
- Photons and electrons lose energy very quickly and stop in the electromagnetic calorimeter.
 - ◊ Photons don't leave signal in the tracking detector.
- Muons can pass through many cm of material before losing their energy.
- Jets from quarks reach the hadron calorimeter and form hadronic showers.
- The distance a particle travels in a calorimeter is used to identify the particle.



Triggers

- The CEM trigger requires (at level 3) the final reconstructed energy of the electron to be $E_T > 18$ GeV with a matching track of $p_T > 9$ GeV/c.
- The PHX trigger requirements at level 3 are $E_T > 20$ GeV, $E_{had}/E_{EM} < 0.125$, and $1.1 < |\eta| < 3.6$ with fully reconstructed clusters and tracks.
- The CMUP trigger at level 3 requires a COT track with $p_T > 18$ GeV whose extrapolation matches hits in the CMU and CMP detectors within a $\Delta x_{CMP} < 20$ cm (difference in x between the track and the cluster) and $\Delta x_{CMU} < 10$ cm.
- The CMX trigger operates very similarly to the CMUP trigger.
- The MET+jets trigger selection is two jets and 35 GeV of missing transverse energy

Background Estimation

- **Top and Electroweak:**

$$N_{p\bar{p} \rightarrow X} = \sigma_{p\bar{p} \rightarrow X} \cdot e_{evt} \cdot e_{tag} \int dt \cdot L$$

PROCESS		CROSS SECTION (pb)
TOP	$t\bar{t}$	6.7 ± 0.83
	Single Top- tchan	1.98 ± 0.25
	Single Top- schan	0.88 ± 0.11
ElectroWeak	WW	11.66 ± 0.7
	WZ	3.46 ± 0.3
	ZZ	1.51 ± 0.2
	Z+jets	787.4 ± 85

- **Non-W:** we fit the E_T distribution of a non-W template and a MC signal template to data to determine the non-W fraction, in the pretag and tag regions.

$$N_{QCD}^{pretag} = F_{QCD}^{pretag} \cdot N_{pretag}$$

$$N_{QCD}^{tag} = F_{QCD}^{tag} \cdot N_{tag}$$

- **W+jets:**

$$N_{W+jets}^{pretag} = N_{pretag} \cdot (1 - F_{QCD}^{pretag}) - N_{ewk}^{pretag} - N_{top}^{pretag}$$

$$N_{W+HF}^{tag} = (N_{pretag} \cdot (1 - F_{QCD}^{pretag}) - N_{ewk}^{pretag} - N_{top}^{pretag}) \cdot f_{HF} \cdot K \cdot e_{tag}$$

$$N_{W+LF}^{tag} = \frac{N^-}{N_{pretag}} \cdot (N_{pretag} - N_{ewk}^{pretag} - N_{top}^{pretag} - N_{W+HF}^{pretag} - N_{QCD}^{pretag})$$

SM Higgs Boson \mathcal{BR} ($H \rightarrow b\bar{b}$) and σ

- SM branching ratios ($H \rightarrow b\bar{b}$) and cross sections for all Higgs masses.

Higgs Mass (GeV/c ²)	\mathcal{BR} ($H \rightarrow bb$)	σ (pb)	$\sigma \times \mathcal{BR}$ ($H \rightarrow bb$) (pb)
100	0.812	0.286	0.232
105	0.796	0.253	0.201
110	0.770	0.219	0.169
115	0.732	0.186	0.136
120	0.679	0.153	0.104
125	0.610	0.136	0.083
130	0.527	0.120	0.063
135	0.436	0.103	0.045
140	0.344	0.086	0.030
145	0.256	0.078	0.020
150	0.176	0.070	0.012

2-jet Expected Signal Events

Process	SVSV	SVJP	SVnoJP
WH100	5.07 ± 0.59	3.53 ± 0.45	13.40 ± 1.06
WH105	4.70 ± 0.55	3.22 ± 0.41	12.08 ± 0.95
WH110	4.10 ± 0.48	2.85 ± 0.36	10.56 ± 0.83
WH115	3.47 ± 0.41	2.39 ± 0.30	8.79 ± 0.69
WH120	2.77 ± 0.32	1.92 ± 0.24	6.91 ± 0.55
WH125	2.27 ± 0.27	1.59 ± 0.20	5.64 ± 0.45
WH130	1.77 ± 0.21	1.23 ± 0.16	4.38 ± 0.35
WH135	1.28 ± 0.15	0.91 ± 0.11	3.16 ± 0.25
WH140	0.87 ± 0.10	0.61 ± 0.08	2.11 ± 0.17
WH145	0.60 ± 0.07	0.43 ± 0.05	1.45 ± 0.11
WH150	0.38 ± 0.04	0.27 ± 0.03	0.91 ± 0.07

3-jet Expected Signal Events

Process	SVSV	SVJP	SVnoJP
WH100	1.23 ± 0.14	0.94 ± 0.13	2.88 ± 0.23
WH105	1.21 ± 0.14	0.90 ± 0.13	2.76 ± 0.22
WH110	1.10 ± 0.13	0.83 ± 0.12	2.57 ± 0.21
WH115	0.99 ± 0.12	0.73 ± 0.10	2.20 ± 0.18
WH120	0.81 ± 0.09	0.61 ± 0.08	1.81 ± 0.15
WH125	0.69 ± 0.08	0.51 ± 0.07	1.54 ± 0.12
WH130	0.58 ± 0.07	0.42 ± 0.06	1.23 ± 0.10
WH135	0.43 ± 0.05	0.32 ± 0.04	0.93 ± 0.08
WH140	0.30 ± 0.04	0.22 ± 0.03	0.65 ± 0.05
WH145	0.21 ± 0.02	0.16 ± 0.02	0.46 ± 0.04
WH150	0.14 ± 0.02	0.10 ± 0.01	0.30 ± 0.02